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Sky at Night

#157 JUNE 2018

REVEALED

The strangest STARS

Discover the stellar oddities that defy the laws of physics

JUNE OBSERVING & IMAGING GUIDE INSIDE

Mapping the MILKY WAY

Why Gaia's billion-star map will revolutionise astronomy

SATURN on show

Ringed planet at its brightest for the year

How to use STELLARIUM

Uncover the planetarium program's hidden features and get more out of stargazing

WATCH THE SKY AT NIGHT

The latest in the hunt for signs of life on Mars

LISTENING OUT FOR DARK MATTER

A new era in the search for the unknown?

VIRTUAL PLANETARIUM

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This month's contributors include...

Gerry Gilmour
Cosmologist

An official investigator for the Gaia mission, Gerry reveals why he's so excited by the second data release. *Page 21*

Sandra Kropa
Science journalist

Sandra has been getting a unique tour of the Solar System thanks to *The Ultimate Interplanetary Travel Guide*. *Page 102*

Pete Lawrence
***Sky at Night* presenter**

As host of our in-depth Sky Guide, Pete tells you everything you need to know about observing the night sky throughout June. *Page 49*

Tim Jardine
Amateur astronomer

Tim's been checking out Atik's first CMOS camera, the Atik Horizon, designed for use with smaller telescopes. *Page 98*

Welcome

Gaia's second data release is set to turbocharge astronomy

This issue our star of the month on page 59 of the Sky Guide is one of the brightest in the sky, Vega. Throughout the summer it's the first star visible as darkness falls and stays with us until daybreak. Astronomers know that Vega is a decidedly unusual stellar object, its rapid spin rate causing it to bulge heavily, giving it a squashed appearance. It's just one of many downright bizarre stars that they have uncovered, and one which features in Elizabeth Pearson's look at some of the most extreme stars in the Universe on page 38.

Many more examples of stellar extremes will no doubt be uncovered following the release of the Gaia mission's second batch of data. Its 3D map of our Galaxy is a watershed moment for all branches of astronomy, making it possible to pinpoint the positions, speeds, colours and brightnesses of over a billion stars in the Milky Way with a whole new level of precision. On page 21, the UK's principal investigator, Professor Gerry Gilmour, explains why this moment is so important, while on page 32 Dr Ben Skuse looks in detail at the journey of discovery that Gaia's vast catalogue has kicked off.

Enjoy the issue!

Chris Bramley Editor

PS Our next issue goes on sale 21 June.

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Sky at Night Lots of ways to enjoy the night sky...

TELEVISION
Find out what *The Sky at Night* team will be exploring in this month's episode on page 19

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C = on the cover

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Get started with The Guide on page 78 and our online glossary at www.skyatnightmagazine.com/dictionary

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JUNE'S BONUS CONTENT

HOW TO FIND IT

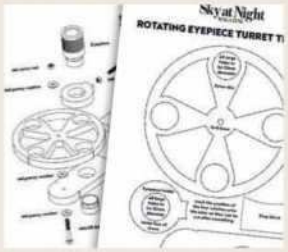
Visit **www.skyatnightmagazine.com/bonuscontent**, select June's bonus content from the list and enter the authorisation code **HHBG7YD** when prompted

THERE'S MORE ONLINE

June highlights

Watch *The Sky at Night*

Humans continue to send probes and orbiters to study Mars, hoping for signs that life once existed on the Red Planet, or that it could in the future. In June's episode, the team learns more about the ExoMars Trace Gas Orbiter and how rovers survive the planet's harsh conditions. Pete Lawrence reveals how to spot the Red Planet in the night sky.



Build a rotating eyepiece turret

Download plans, diagrams and additional images to help with this month's *How To…* project on page 82.

Listening out for dark matter

Professor Gray Rybka discusses a new mission to solve one of the Universe's most enduring mysteries.

Noctilucent clouds: all you need to know

Download videos, time-lapses and guides to reveal the science behind NLCs, and how to observe them.

And much more…

- ▷ **Hotshots gallery**
- ▷ **Eye on the sky**
- ▷ **Extra EQMOD files**
- ▷ **Binocular tour**
- ▷ **Equipment review guide**
- ▷ **Desktop wallpaper**
- ▷ **Observing forms**
- ▷ **Deep-sky tour chart**

EVERY MONTH

Virtual Planetarium

With Paul Abel and Pete Lawrence

Explore June's night-sky highlights with Paul and Pete

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YOUR BONUS CONTENT A gallery of these and more stunning space images

Happy birthday Hubble

Astronomers have celebrated the ongoing legacy of the famous orbiting observatory with a beautiful capture of the Lagoon Nebula

HUBBLE SPACE TELESCOPE, 19 APRIL 2018

The Hubble Space Telescope reached a milestone of 28 years in space on 24 April 2018. In the months beforehand, astronomers turned its viewing power onto this dazzling cosmic cloud.

The Lagoon Nebula is about 4,000 lightyears away from Earth but is so vast that Hubble can't fit the entire cloud into its view. It would take a ray of light 55 years to travel the breadth of the entire nebula, yet this image shows a small section just four lightyears across.

Like most nebulae, the Lagoon is illuminated by the ultraviolet radiation of large hot stars. This radiation also sculpts the dark wisps of cosmic dust that twist through the nebula, creating dense shadows as the intense light is blotted out. At the centre of this image is Herschel 36, a bright star that manages to shine through the dark dust.

NASA/ESA/STSCI

▲ Ring of storms

NASA JUNO SPACECRAFT, 11 APRIL 2018

Juno's Jovian Infrared Auroral Mapper instrument can observe Jupiter's weather as far as 70km beneath the clouds, enabling NASA scientists to learn more about the planet's tempestuous atmosphere. Here it reveals a huge cyclone at Jupiter's north pole, surrounded by a ring of smaller storms.

▼ Globular golden-ager

HUBBLE SPACE TELESCOPE, 7 APRIL 2018

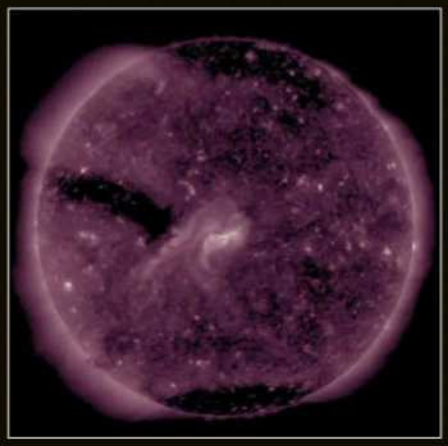
At 13.4 billion years old, this globular cluster is virtually as ancient as the Universe itself. NGC 6397 is about 7,800 lightyears away, making it one of the closest globular clusters to Earth. The dazzling multi-coloured specks reveal red giants, massive blue stars nearing the end of their livse and smaller white stars similar to our own Sun.

NASA/JPL-CALTECH/SWRI/ASI/INAF/JIRAM, NASA/ESA AND T. BROWN AND S. CASERTANO (STSCI), ESO/NASA/ESA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)/F. VOGT ET AL, SDO/NASA, NASA/CXC/GSFC/S. WALKER/ESA/XMM/ROSAT

◀ Blue marks the spot

VERY LARGE TELESCOPE, 5 APRIL 2018

At the centre of the red ring of gas is an isolated neutron star (the blue dot). It was found by a team examining the gaseous ring, which is expanding through the remains of an exploded star in the Small Magellanic Cloud.



▲ From holes to poles

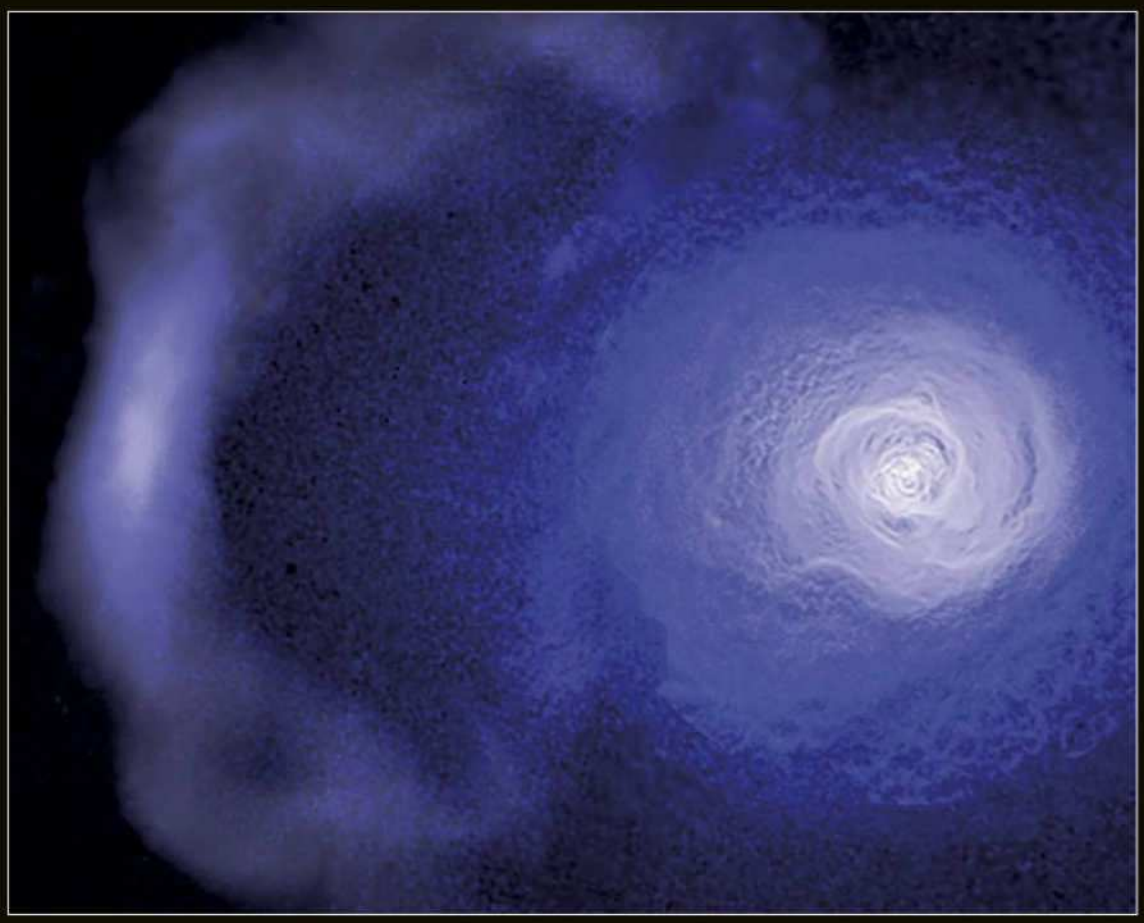
NASA SOLAR DYNAMICS OBSERVATORY, 4 APRIL 2018

Scientists spotted three huge coronal holes on the surface of the Sun. Charged particles burst out from these regions and, if they react with Earth's magnetosphere, create aurora displays viewable from the north and south poles.

▶ Cosmic cold front

CHANDRA X-RAY OBSERVATORY, 3 APRIL 2018

The smoky structure on the left of this image is a 'cold front' speeding away from the Perseus Cluster at about 480,000km/h. It was created as a smaller cluster passed by the central core of the Perseus, the gravitational pull causing gas in the core to swirl around and generate the cold front. The structure spans about two million lightyears and is about five billion years old.



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Bulletin

The latest astronomy and space news written by **Elizabeth Pearson**

PLUS CUTTING EDGE

Our experts examine the hottest new astronomy research papers

TESS will be searching for transits – the regular, periodic dimming of stars that occurs when a planet passes in front of its star from an observer's point of view

NASA/GSFC

Planet hunter launched into orbit

The TESS mission will search for planets around bright stars

NASA successfully launched its latest exoplanet-hunting satellite, the Transiting Exoplanet Survey Satellite (TESS), from Cape Canaveral on 18 April, at 18:51 EDT (22:51 UT). TESS will search for exoplanets across 85 per cent of the sky, a much larger area than previous missions such as Kepler.

"TESS will be a game-changer for our understanding of planets and the stars that they orbit," says Daniel Huber, an astronomer from the University of Hawai'i. "The sheer number of stars for which TESS will provide data – 10 to 100 times more than Kepler – is bound to yield some very exciting surprises."

By the time of publication, TESS should have moved into its final 13.7-day orbit around Earth and be performing its final tests and checks. It will commence its science mission this summer, spending a year surveying the southern ecliptic hemisphere, then the northern hemisphere the year after. TESS is expected to find at least 1,500 planets, including some super-Earths, which could be in their stars' habitable zones.

"We are thrilled that TESS is on its way to help us discover worlds we have yet to imagine, worlds that could possibly be habitable, or harbour life," says Thomas Zurbuchen, the associate administrator of NASA's Science Mission Directorate.

TESS will examine stars 30 to 100 times brighter than those imaged by Kepler, which means it will be much easier for follow-up observations to probe their atmospheres and measure their temperatures.

"With missions like the James Webb Space Telescope [currently due to launch in 2020] to help us study the details of these planets, we are ever closer to discovering whether we are alone in the Universe," says Zurbuchen.

▸ **See Comment, right**

COMMENT
by Chris Lintott

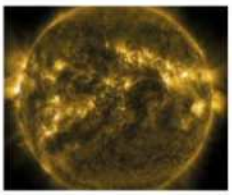
It's been a very long while since I've been as excited about a mission as I am about TESS. Finding planets around nearby, bright stars is the stuff of science fiction, and now it's about to become a reality.

It's not just that these planets will be close enough and bright enough to make them much easier to study than Kepler's distant haul. TESS's discoveries are likely to be the planets we know most about for centuries to come. If we ever get to the point where the first human voyagers set sail beyond the bounds of our own Solar System, our distant descendants will likely set a course for a planet found by TESS.

It's a very big mission for a relatively small spacecraft. Once an initial checking-out phase has been completed, all of TESS's data will quickly become public, no doubt setting off an exoplanet hunting boom. I can't wait to see what's waiting to be found.

CHRIS LINTOTT co-presents *The Sky at Night*

NEWS IN BRIEF



SEARCH FOR SUN'S SIBLINGS

The chemical profiles of over 350,000 stars have been mapped as part the Galactic Archaeology with HERMES survey, which had its first data release in April. Once finished, the survey will have measured the chemical fingerprints of over a million stars, allowing researchers to track which stars were born in the same cluster. One of the main goals of the survey is to try to track down the Sun's long-lost siblings, which formed alongside it but were then swept out through the Galaxy.

AMATEURS FIND EXOPLANET

For the first time an exoplanet has been found using images by amateur astronomers. During the Kourovka Planet Search, amateurs took wide-field CCD images of stars at low Galactic latitudes, which professional astronomers analysed. They found a transiting exoplanet, KPS-1b, roughly the size of Jupiter, orbiting once every 1.7 days. Inspired by the success, the team will continue surveying high-density star fields along the Galactic plain hoping to find more hot-Jupiters like KPS-1b.

NASA/SDO, NASA/ESA/G. BACON (STSCI) AND N. MADHUSUDHAN (UC), NASA/JPL-CALTECH/T. PYLE, ISTOCK, NASA/ESA/THE HUBBLE HERITAGE (STSCI/AURA)-ESA/HUBBLE COLLABORATION AND A. EVANS (UNIVERSITY OF VIRGINIA CHARLOTTESVILLE/NRAO/STONY BROOK UNIVERSITY), NASA/JHUAPL/SWRI, ESA/HUBBLE & NASA

Binary stars appear to create a region of instability that moves outwards, ejecting planets from the system

Twin stars CAST OUT PLANETS

Tightly orbiting binary pairs are bad news for exoplanets

Binary stars which are locked in a tight orbital embrace could be throwing away their planets. In recent simulations of short-term binary stars that rotate around each other once every 10 days or fewer, nearly all of the planetary systems modelled ejected at least one of their planets.

This find explains why so few circumbinary planets – planets orbiting two stars – have been discovered. Their absence comes about because when two stars orbit each other very closely, they begin a gravitational tug-of-war.

"Tidal forces transport angular momentum from the stellar rotations to the orbits. They slow down the stellar rotations, expanding the orbit," says David Fleming, from the University of Washington, who led the study.

As well as expanding, the orbit shape also changes from an ellipse to a near perfect circle. This disrupts the star system's gravitational balance, flinging some of the planets from their orbits. In a number of the simulations, this upset the balance even more and created a cascading effect with planets being thrown out one after another.

Making matters even more difficult for these planets is that binary stars appear to have a 'region of instability' created by the gravitational pulls of the two stars.

"There's a region that you just can't cross," explains Fleming. "If you go in there, you get ejected from the system. We've confirmed this in simulations and many others have studied the region as well."

The location of this limit changes – as the stellar orbit increases it moves outwards, potentially crossing the orbits of previously stable planets and ejecting them from the system. It also appears that planets pile up just beyond this stability limit, but the reasons why are not fully known at present. It could be that they form there or they could migrate to this point from further out.

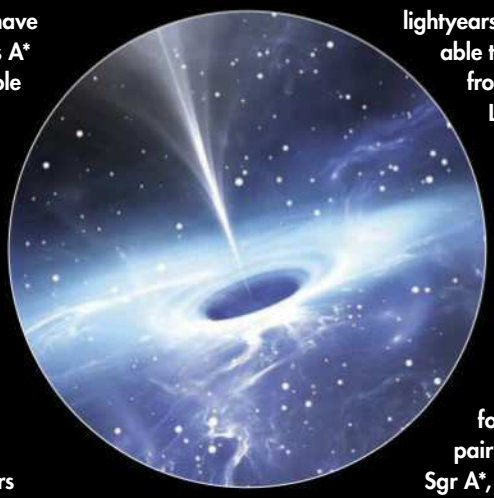
The findings could help future exoplanet hunts concentrate their searches in the spots that are the most likely to have planets. The tightest binary currently known to host a planet, Kepler 47, has a period of 7.45 days and so the team suggests that any mission attempting to find habitable planets around such systems should focus on stars with orbital periods longer than 7.5 days.

https://www.washington.edu

Milky Way's blacker centre

A dozen small black holes have been found near Sagittarius A* – the supermassive black hole at the centre of our Galaxy. The region around Sgr A* is a perfect breeding ground for the kind of massive stars that create stellar mass black holes, so there should be thousands there, but very few have been seen.

"There are only about five dozen known black holes in the entire Galaxy – which is 100,000 lightyears wide – and there are supposed to be 10,000 to 20,000 of these things in a region just six lightyears wide that no one has been able to find," says Chuck Hailey from Columbia Astrophysics Lab, who led the study.



▲ The Milky Way's missing black holes are finally starting to reveal themselves

Researchers found the new black holes using archival data from the Chandra X-ray Observatory, looking for the dim X-ray glow emitted by a black hole that has paired up with a low-mass star. They found 12 black hole-star pairs within three lightyears of Sgr A*, suggesting that there could be between 300 and 500 such binary objects in the region.

http://chandra.harvard.edu

Galaxy's baby-boom is over

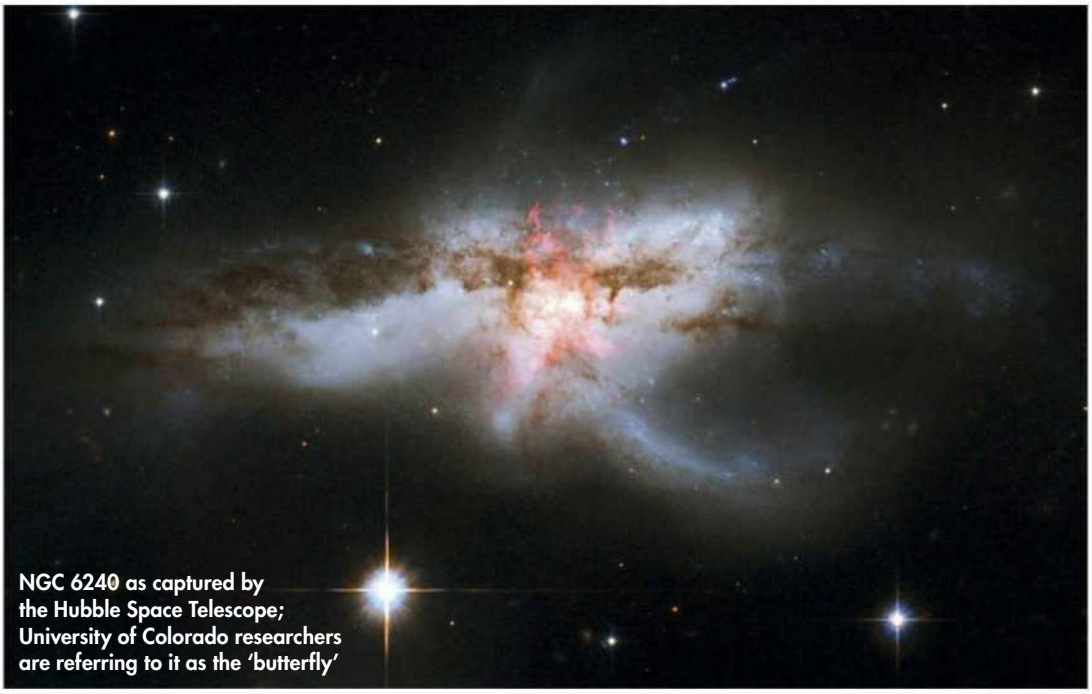
NGC 6240 has stopped its own growth by throwing out all its gas

Astronomers have caught a recently merged galaxy, NGC 6240, in a unique phase of evolution: the galaxy's initial 'baby-boom' is coming to an end.

NGC 6240 is currently rapidly forming stars, as most galaxies do after they first merge. Once stellar winds push gas out of the galaxy, however, their growth slows. This is further exacerbated when the merged galaxies' central black holes begin to combine – a process that is beginning to happen in NGC 6240 – as the gravitational disruption ejects even more gas. The study found NGC 6240 is losing around 100 solar masses of gas a year.

"It is forming stars intensely now, so it needs the extra strong kick of two winds to slow down that star formation and evolve into a less active galaxy," says Julie Comerford from the University of Colorado, who took part in the study.

https://www.colorado.edu/today/



NGC 6240 as captured by the Hubble Space Telescope; University of Colorado researchers are referring to it as the 'butterfly'

NEWS IN **BRIEF**

PLUTO'S MOON SITES NAMED

The features of Pluto's moon, Charon, have received their first official names from the International Astronomical Union (IAU), the recognised authority for naming celestial bodies. Inspired by fictional stories of exploration, they include Argo Chasma (named after the ship in *The Argonautica*) and Kubrick Mons (named after *2001: A Space Odyssey* director Stanley Kubrick). They were proposed by NASA's New Horizons team, following a public campaign.

NOVA FLARES IN PERSEUS

The brightest nova in northern skies since 2013 erupted in late April in Perseus, growing easy enough to see with binoculars by 29 April, reaching mag. +6.2 before fading. It could be found at RA 04h 43m, Dec +47d 21m, close to the border with Auriga. It appears to be an eruption by dwarf nova V392 Persei, a U Geminorum type of variable where one star strips material from a companion. V392 Persei normally varies between mag. +14 and mag. +17 so this extreme flaring is unprecedented.

CUTTING EDGE

Our experts examine the hottest new research

Are black-body stars too perfect to be true?

Because these stars adhere to text-book rules, that makes them bizarrely far from being text book

MARK GARLICK

▲ **Far from a black and white case: are some curious black-body stars actually white dwarves?**

Finding a new type of object is incredibly rare in astronomy; while there is plenty still to be discovered, our census of what *sorts* of things the Universe might throw at us is assumed to be complete. It was surprising, therefore, when two Japanese astronomers announced last year that hidden amongst the hundreds of millions of stars studied by the Sloan Digital Sky Survey were a few that didn't look like anything else.

It was the stars' spectra that was unusual, appearing to come straight from a physics textbook. They had what's known as a 'black-body' spectrum – one in which the brightness at any given wavelength was perfectly described by a simple physical law. Most stars have spectra which are close to being black-bodies to some extent, but we normally also see features resulting from the presence of atoms and molecules as well as signs of internal structure. Not here: these black-body, or BB, stars looked completely boring. Which, of course, makes them very, very interesting indeed.

A new paper from a team led by Aldo Serenelli of Barcelona, investigates the possibility that these are white dwarves, the dead cores of what would once have been normal stars. White dwarves are extremely common – one orbits as a companion of Sirius, for example – and consist of a dense core surrounded by some remnants of an atmosphere, typically consisting of some mix of hydrogen and helium. That atmosphere means that we don't just see a black-body spectrum; most white dwarves show features in their spectrum which are created by the absorption of light by helium and other elements on top of a basic black-body pattern.

Serenelli and friends suggest that the BB stars are white dwarves which, for some reason, don't have these features. Perhaps the atmosphere is too thin to be seen, or maybe the glow from the star itself is too feeble to excite helium in the atmosphere.

But does this make sense? The signs look good. A black-body spectrum has the property of linking the colour of a source to its temperature, and this backs up the team's hypothesis: the colours suggest a temperature of between 7,000°C and 11,000°C. That's hot enough that the white dwarf would appear in our surveys, but not hot enough to produce a detectable helium feature, even if there is lots there.

> "These black-body, or BB, stars appeared to be completely boring. Which, of course, makes them very, very interesting indeed"

The basic idea – that these things are unusual white dwarves – seems convincing, but the details remain unclear. In particular, the authors can't tell whether these unusual objects have a mostly helium atmosphere with just a trace of hydrogen – in which case they will weigh in at about half a solar mass – or if they are more massive white dwarves with no hydrogen at all.

The confusion is understandable, not least because we don't actually know how far away these stars are. That's something the Gaia mission, currently mapping the nearest billion stars, should be able to help with. Sort that out, and these unusual stars will be a good test of our understanding of how most stars end their lives.

CHRIS LINTOTT is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project

CHRIS LINTOTT was reading… *On the nature of black-body stars* by Aldo Serenelli, Rene Rohrmann and Masataka Fukugita. **Read it online at https://arxiv.org/abs/1804.01236**

'Global' telescope in action again

Second run for worldwide project investigating the centre of our Galaxy

The team hopes to see a bright ring of light, made up of photons, orbiting close to the event horizon. This is one of their simulations

The Event Horizon Telescope (EHT) has completed a second observation run, attempting to capture the shadow of the black hole at the centre of our Galaxy. Between 18-29 April radio telescopes worldwide combined their observations to create a virtual telescope the size of Earth.

"For the first time we've included a new site in Greenland," said Shep Doeleman, EHT's director, when *BBC Sky at Night Magazine* contacted him. "The EHT now truly spans the globe, from Greenland to the South Pole."

The project had its first observation run in April 2017 and the amount of data produced was so vast that the team is still processing it; also there was a delay getting the hard drives from the South Pole. The current goal is to have last year's data translated into images by the end of 2018.

https://eventhorizontelescope.org

Latest dark matter search begins

A new detector is ready to start searching for one of the potential components of dark matter – a theoretical particle called an axion.

Axions are hypothetical elementary particles that were first theorised to explain issues with the Standard Model of particle physics. If they do exist, they have so far evaded detection. But after 30 years of development the Axion Dark Matter eXperiment (ADMX) has finally achieved the sensitivity needed to find them using precise magnetic detectors known as super conducting quantum interference devices.

To learn more, listen to our interview with Gray Rybka, co-spokesperson for ADMX and assistant professor of physics at the University of Washington, in this issue's Bonus Content (see page 5).

http://depts.washington.edu/admx/

▲ Axion hunting begins at the University of Washington's Center for Experimental Nuclear Physics and Astrophysics

LOOKING BACK THE SKY AT NIGHT

2 June 1985

On the 2 June 1985 episode of *The Sky at Night*, Patrick Moore talked about the upcoming Galileo mission. Although the spacecraft was bound for the planet Jupiter, it was the probe's journey through the asteroid belt that Patrick was interested in.

Galileo was set to be the first spacecraft ever to make a close approach to an asteroid. On the show, Patrick discussed the initial target, an asteroid named Amphitrite. Unfortunately, the mission was then delayed by five months, eventually launching on 18 October 1986, meaning that it missed out on its opportunity to meet up with Amphitrite.

Instead, the spacecraft flew past the asteroids Gaspra and Ida. Galileo transmitted back images of the asteroids, revealing them both to be heavily cratered S-type, or stony, asteroids. The images also revealed that Ida was not alone but had a tiny moon only 1.4km in diameter, which was named Dactyl.

▲ Stony Ida was one of the first asteroids to be studied up close

C-K CHAN/D PSALTIS/F OZEL, MARK STONE/UW, NASA/JPL, NASA/BILL INGALLS, ANJA RUTISHAUSER

NEWS IN **BRIEF**

NASA'S NEW FIGUREHEADS

Jim Bridenstine was sworn in as NASA's new administrator on 23 April. Congress only approved his appointment by a narrow margin, as some members were concerned over his lack of experience in the aerospace sector, though he served on the Science, Space and Technology Committee while in House of Representatives. He will be assisted by a new Chief Scientist, Jim Green, who was director of NASA's Planetary Science Division for over a decade.

EUROPA ON EARTH?

Geologists have recently discovered a pair of salty lakes hidden beneath a terrestrial glacier, providing a potential analogue for the subsurface oceans of icy moons such as Europa. The two lakes are 750m below the Canadian High Arctic and have been cut off from the atmosphere for 120,000 years. By studying how life has evolved in them, exobiologists can gain a better understanding of whether it is possible for life to exist on the icy moons.

CUTTING EDGE

Our experts examine the hottest new research

Soon we could be greeting our interstellar visitors

'Oumuamua visited us from another star in 2017 but could we actually intercept future cosmic tourists?

MARK GARLICK

▲ **New research suggests we could have visitors like 'Oumuamua as often as once a decade**

The asteroid 1I/2017 U1, better known as 'Oumuamua (meaning 'scout' in Hawaiian), has generated a great deal of excitement amongst astronomers and planetary scientists. This remarkable object was spotted by the Pan-STARRS telescope system last October, and within a week scientists had determined that it was on a hyperbolic trajectory: travelling so fast that it wasn't gravitationally bound to the Sun and must therefore have come from beyond the Solar System. 'Oumuamua is the first ever interstellar asteroid to be discovered, long ago ejected from its birth star system and orbiting around the Galaxy ever since.

With such a novel object to study, teams around the world scrutinised 'Oumuamua to learn as much as they could about it before it streaked back out of the Solar System. Darryl Seligman and Gregory Laughlin, both in the Department of Astronomy at Yale University, have reviewed the results of all of these observations and what catches the eye is their calculations of how common visits from such interstellar objects (ISOs) might actually be.

While 'Oumuamua was detected by Pan-STARRS, a far more capable sky survey, the Large Synoptic Survey Telescope (LSST), will become operational next year. Any interstellar object is most likely to approach the Solar System from the solar apex – the direction of the Sun's relative motion through our local region of the Galaxy – which is in the direction of the constellation Serpens.

Taking into account details such as the likely size and reflectivity of any interstellar asteroids, the illumination angle between the arriving ISO and the Earth, as well as the sensitivity of the LSST itself, Seligman and Laughlin have calculated that the telescope ought to be able to detect about one per cent of all incoming interstellar objects. Using an estimate for the total number of such interstellar objects roaming through our region of the Galaxy, they go on to predict that the LSST will detect several interstellar objects passing through the inner Solar System every year.

And this, say Seligman and Laughlin, presents us with a unique opportunity. Interstellar asteroids like 'Oumuamua represent deliveries of samples from other planetary systems, and an enormous amount could be learned if only we could get a closer look at one. If we spot an incoming ISO early enough, a space probe could be launched on an intercept course.

> "If we spot an incoming interstellar object early enough, a space probe could be launched on an intercept course"

Considering the very high velocities of ISOs on hyperbolic trajectories through the Solar System, an orbiter/lander mission (such as the Rosetta mission to comet 67P, for example) would be impossible. But an impactor mission, like the Deep Impact probe to comet Tempel 1, would be eminently plausible, argue Seligman and Laughlin. Such a mission design would involve launching the probe on an intercept course soon after the ISO was detected, which would then release 16 metal balls to slam into the object to throw up material to be analysed as the probe passes through the plume.

And we might not have to wait too long for such a revolutionary mission. Seligman and Laughlin calculate that appropriate opportunities would come up roughly once a decade. By the year 2030 a robotic emissary from Earth could have made contact with a visitor from interstellar space.

LEWIS DARTNELL is an astrobiology researcher at the University of Westminster and the author of *The Knowledge: How to Rebuild our World from Scratch* (www.the-knowledge.org)

LEWIS DARTNELL was reading… *The Feasibility and Benefits of In Situ Exploration of 'Oumuamua-Like Objects* by Darryl Seligman and Gregory Laughlin
Read it online at https://arxiv.org/abs/1803.07022

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What's on

Our pick of the best events from around the UK

CHELTENHAM SCIENCE FESTIVAL, MILLS OBSERVATORY, ESO/MATISSE CONSORTIUM, CARDIFF ASTRONOMICAL SOCIETY, NASA/JPL-CALTECH

Cheltenham Science Festival 2018

Various venues, 5-10 June 2018

One of the UK's biggest science festivals returns to ponder the planet we live on and the Universe around us.

Astronomer Dhara Patel looks at the chances of finding another Earth-like planet and asks *How Special Is Our Solar System?*, while Jim Al-Khalili explores the theories of *Entanglement, Teleportation and Wormholes*.

Looking back at one of the key figures in our understanding of the Universe, cosmologist Andrew Pontzen hosts *Beyond Einstein: The Future of Physics*. In *An Impractical Guide to Leaving the Planet* TV science presenter Dallas Campbell explores humanity's desire to leave Earth, from early rocket science to Elon Musk's ambitions to reach Mars – a must-see for anyone who has ever wanted to travel to the stars.

TV presenter Maddie Moate is looking for recruits for her Astronaut Academy. *Maddie's Mission to Mars* features live science demos and reveals how rockets work and how space suits are made.

From gravitational wave observatories to neutrino detectors and kilometre-sized radio receivers, *Beyond Light: The Future of Astronomy* looks at the modern observatories seeking out the invisible.

Stargazing in the Gardens sees Cotswold Astronomical Society invite would-be astronomers of all ages to a supervised evening of stargazing in Cheltenham's Imperial Gardens.

www.cheltenhamfestivals.com/science

BEHIND THE SCENES

THE SKY AT NIGHT IN JUNE

BBC Four, **10 June,** 10pm (first repeat BBC Four, **14 June,** 7.30pm)*

Juno has given us a new insight into Jupiter's gravity, aurorae and atmosphere

JUPITER, GOD OF THUNDER

NASA's Juno spacecraft is currently in orbit around Jupiter, collecting data and revealing the secrets of the stormy gas giant. A month ahead of the probe's planned deorbit into Jupiter's atmosphere, the team looks back on what the Juno mission has revealed so far, and what discoveries might be yet to come.

Check www.bbc.co.uk/skyatnight for subsequent repeat times

Summer star shows

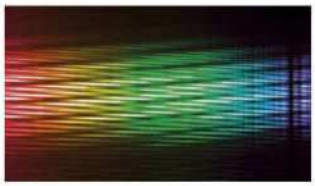
Mills Observatory, Glamis Road, Dundee, from June

A season of summer planetarium spectaculars begins at Mills this month. Bring your little ones to a children's planetarium show on 9 June at 12.30pm and get involved in astronomy-themed activities with Saturday Stars, starting at 2pm. The first summer planetarium show for grown-ups begins 23 June at 2pm, guiding you through the night sky. For ticket prices and to book, visit the observatory website.

www.leisureandculturedundee.com/mills-home

Practical stellar spectroscopy

Great Ellingham Recreation Centre, Attleborough, Norfolk, 8 June 2018, 7.30pm



Spectroscopy is a technique used by astronomers to extract information from the light that is emitted by celestial objects. In this talk for Breckland Astronomical Society, author Jack Martin discusses his own spectroscope and observatory, and reveals what splitting starlight can tell us about the Universe. Admission is £2 or £1 for under 16s. For more information, visit the Breckland AS website.

www.brecklandastro.org.uk

Solar observing in the Beacons

National Park Visitor Centre, Libanus, Brecon, 23 June, 10am-4pm

Join Cardiff Astronomical Society in the Brecon Beacons for a chance to look at our nearest star close to the summer solstice. Solar telescopes will be set up for the event, offering a safe way of observing the dynamic surface of the Sun (weather permitting) with experienced Cardiff AS astronomers. This public event is free and family friendly, but car parking charges will apply.

www.cardiff-astronomical-society.co.uk

MORE LISTINGS ONLINE

Visit our website at **www.skyatnightmagazine.com/whats-on** for the full list of this month's events from around the country.

To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the web page.

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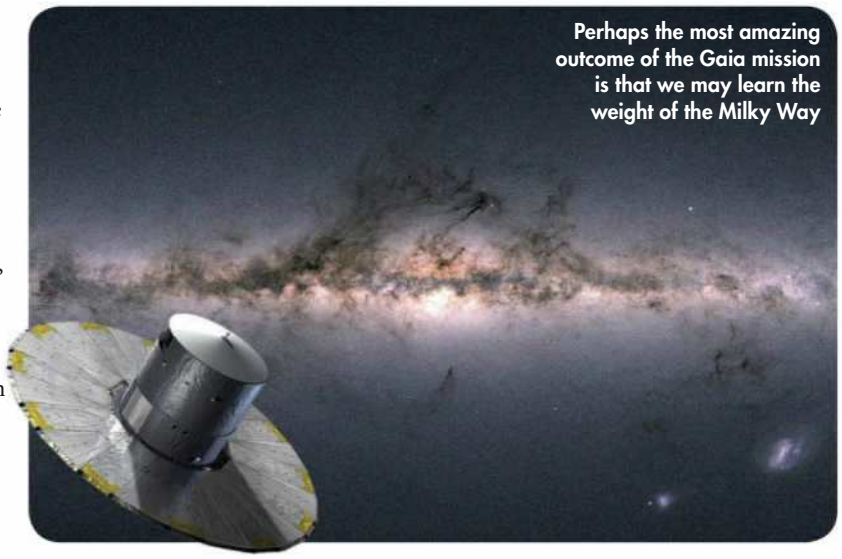
A PASSION FOR SPACE

with **Professor Gerry Gilmour**

The Gaia mission isn't merely creating a map; its data will enlighten almost every branch of astrophysics

As I was selecting which awesome images and videos of Gaia's second data release to use for the press announcement, I found myself recalling the following promise, written 25 years ago in the original Gaia mission proposal: "Astrometric measurements provide model-independent estimates of basic geometrical and kinematical properties of astronomical sources. Gaia will provide an immense quantity of extremely accurate astrometric and photometric data from which all branches of astrophysics will benefit."



Perhaps the most amazing outcome of the Gaia mission is that we may learn the weight of the Milky Way

ESA–D. DUCROS/2013; ESA/GAIA/DPAC

Those benefits have begun to be realised, thanks to the heroic efforts of large teams of engineers and astronomers in many countries over many years, along with ESA and the national agencies who fund them.

The Gaia data release on 25 April 2018 was an exceptional event in scientific history. For the first time ever, humankind has a realistic image of the part of the Universe in which we live. We have measured well over a billion stars with such high precision that we know where they are and how they move. For seven million of them we also have, from Gaia, precise line-of-sight (radial) velocities, so we know all three space coordinates and all three associated velocities, giving us our first six-dimensional view of our local Universe

Our Milky Way is a dynamic place. To understand it one must measure the dynamics: where stars are and how they move. Every star contains information on its origins; when and where it formed tell us the history of star formation, structure and mergers across the Galaxy. The elements from which a star is made tell us how many long-gone massive stars exploded in that place. Stellar remnants, especially white dwarf stars, map the history of stellar evolution.

Weighing the Galaxy

This is now all available in astonishing yet believable detail. Perhaps most fundamentally, the combination of positions and velocities makes it viable to weigh the Galaxy. In the very outer Milky Way, Gaia's precise distances and orbits determine the 3D distribution of the total mass of our Galaxy, and the individual masses of the many Galactic satellites. Closer to home, we can determine the distribution of dark matter to a much better degree. As well as explaining what holds our Milky Way together and our Sun in its orbit, this information is key to experiments into finding the elementary particles that probably make up dark matter.

On a smaller scale, Gaia has increased the precision determination of asteroid orbits by a factor of 100. This not only improves our knowledge of these remnants of the Solar System's formation, but also provides more precise tests of General Relativity. On the largest scales, Gaia defines cosmological distance using both the classic extragalactic distance scale, and independent methods, such as gravitationally lensed quasars, of which several thousand lie in Gaia's cornucopia. These are exciting times!

PROFESSOR GERRY GILMOUR is the UK Principal Investigator in the Gaia Data Processing and Analysis Consortium

▸ Read more about Gaia's second data release in our feature on page 32

Experience a summer spectacle in Spain's night sky

Join expert astronomer **Pete Lawrence** for two nights viewing the majestic Perseid meteor shower

Credit - Pete Lawrence

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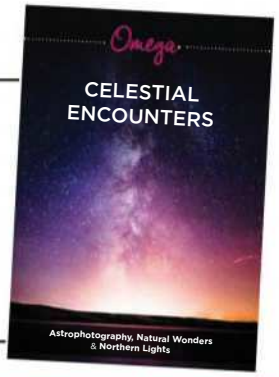

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JON CULSHAW'S

EXOPLANET EXCURSIONS

Jon travels 1,304 lightyears to witness two stars engaged in a cosmic dance

There's a binary star system 1,304 lightyears away in the constellation of Leo that will show us a sight never seen before in any of our previous excursions. It needs to be visited in person in order to truly appreciate the spectacle: with its apparent magnitude of +17.5, a very large telescope indeed would be required to observe the system from Earth.

The particular fascination with this system is that it is cataclysmically variable: two stars twinned and locked into a tight orbit with each other. They complete such an orbit in an extremely brisk 1.5 hours. A trip in my trusty ship, the Perihelion, will allow us to observe how such a stellar orbital dance appears in an alien sky from the surface of an alien world.

The description that comes to mind is Mevlevi Whirling Dervishes performing a gyroscopic display on a minbogglingly vast scale. Even greater drama comes from the system's alarmingly titled 'cataclysmic variable' status. Material is being ripped away from one, a red dwarf star, by the other, a white dwarf star, which has the greater gravitational pull. The matter torn away forms an accretion disc, which then spirals downwards onto the white dwarf's surface.

There is one confirmed, mammoth of an exoplanet orbiting these two interlocked stars: DP Leonis b, which is six times the mass of Jupiter and orbits once around its parent star in 23.8 years at a distance of 8.6 AU.

Landing the Perihelion on a Titan-sized moon of DP Leonis b gives us a majestic view of this gas giant. Bands of steely charcoal grey and sulphurous yellow exude a sense of unapproachable toxicity. Thankfully, the atmosphere of the moon we've settled on is sufficiently benevolent and has a surface resembling a monochrome Lanzarote.

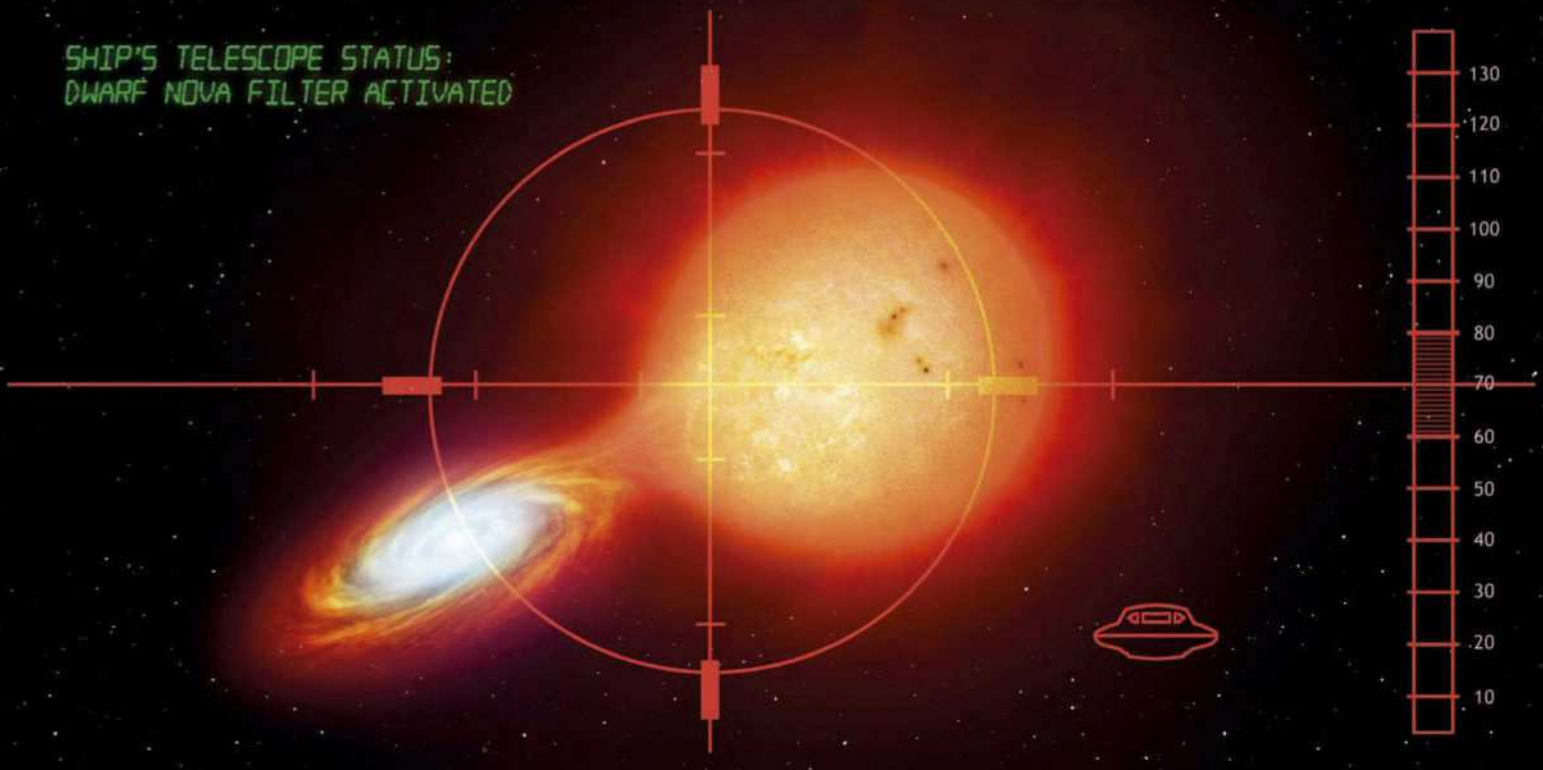
The moon's landscape has small zones of sufficient flatness which allow my ship's telescope to observe (with an appropriate filter, naturally) the incredible phenomenon I was hoping to view on this trip – a 'dwarf nova'.

The red dwarf and white dwarf so close together create a blended, waxy light appearing like the overlapping discs of the old ATV logo. The visual effect as the white dwarf tears material away from its red dwarf neighbour manifests as a silvery light, piercing the view like the momentary glare of a lighthouse beam shining directly in your eyes. It appears almost as if the two stars were being arc-welded together by a very ambitious cosmic engineer.

I try to picture these two interacting objects in the familiar, blue, summer sky back on Earth. Being so accustomed to the fixed disc of light provided by the Sun to the Earth, seeing this kind of stellar activity – like a great celestial lava lamp – is absolutely beguiling. 'Cataclysmically variable' looks a lot more harmoniously orderly from here.

JON CULSHAW is an impressionist, comedian, and guest on *The Sky at Night*

MAIN ILLUSTRATION: MARK GARLICK, SPACECRAFT: PAUL WOOTTON, PHOTO: EMMA SAMMS



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This month's top prize: four Philip's books

PHILIP'S

The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Mark Thompson's *Stargazing with Mark Thompson* and Heather Couper and Nigel Henbest's *2018 Stargazing*.

Tales from THE EYEPIECE

Stories and strange tales from the world of amateur astronomy by Jonathan Powell

After having read some articles on hunting for fallen meteorites, I decided to have a go myself in some nearby mountainous terrain. So as not to break my back while foraging, I invested in some strong neodymium magnets and attached them to the bottom of a 5-wood golf club, which I could swing back and forth over the ground. I mentioned this novel technique in some of my writings and the search method was given airtime on a BBC Radio Four programme about hunting for meteorites. I freely admit I'm rubbish at golf – having once been asked to move down the stalls of a driving range because I kept slicing the ball over the boundary fence – but when looking for meteorites with my golf club, it certainly was a good walk not spoiled.

Email your own tales to Jon at TalesfromtheEyepiece@themoon.co.uk

Jonathan Powell is the astronomy correspondent for the *South Wales Argus*

NASA/JPL-CALTECH/SWRI/MSSS/MATT BREALEY/GUSTAVO B C

MESSAGE OF THE MONTH

Moon-inspired penguin

Ever since they were little, our two children, Louis (10) and Holly (7), have been keen amateur astronomers. They often spend evenings on non-school days looking through the eyepiece of our 8-inch Newtonian telescope. Their favourite object of interest by far is the Moon. Louis is fascinated by the changing phases while Holly enjoys the beauty of the rocky terrain.

As well as having an interest in all things heavenly, they both enjoy visiting our local Sea Life Sanctuary at Hunstanton in Norfolk. During April, the Sanctuary gained two new female penguin chicks. A competition was launched to suggest names for the young birds and Louis and Holly were eager to enter, suggesting the names Luna and Sol. To their complete amazement, the name Luna received over 75 per cent of the votes. At least now, if the skies over Norfolk are too cloudy for stargazing, you can still see Luna at the Hunstanton Sea Life Sanctuary!

Louis and Holly brought a little bit of space to a sea life sanctuary

Andrew Richens, Long Sutton, Lincolnshire

Well done Louis and Holly, what an apt name for the little creature! ***– Ed***

The light stuff

Allan Howard's article 'Seize the Night' (page 42, April 2018 issue) correctly stated that careful lighting can be compatible with admiring the splendours of the night sky. Dark-sky campaigners realise that it is lighting professionals who will ultimately solve the problems of light pollution with optimum luminaire designs, 'intelligent' and remotely controlled light sources, and spectral choices that respect the night-time environment and circadian cycles. It is important to remember that exterior lights should be directed downwards much as possible, and only used when and where absolutely necessary.

It is a sad fact that it's difficult to find well-directed lights in many big DIY retailers. Further, we believe that 'security' lights ought to be called exterior lights: such lights are no guarantee that malefactors will avoid the premises that they light. After all, who benefits from an outside light on

Tweets

Sorcha Lewis
@xSorchaLewisx • Apr 1
Love living in this beautiful Elan Valley @TheElanValley @skyatnightmag It makes getting out for lambing a joy on clear nights

SOCIETY in focus

▲ The North Wales Astronomy Society had a terrifying lesson in space bacteria

April's meet-up for North Wales Astro was a quiet observing evening by recent standards – which the thick cloud and mist probably had a hand in. Luckily, we were prepared with some short talks to entertain those brave enough to venture out on this cold and damp spring evening.

First came the notices, then a look at the society's outreach that month. We encourage members to post their images and sketches on our Facebook page, and after showing off the most recent handiwork I did a short presentation on what we could expect to see other than clouds in April.

Members were challenged to observe some of the spring delights, such as Markarian's Chain and Bode's Nebula (M81), with a few globular clusters thrown in for good measure. Halfway through the evening we took a break for a chat, some refreshments and our ever-popular raffle.

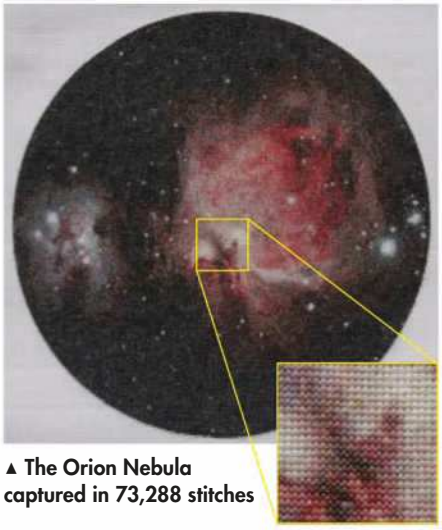
This month our former Chair Arie Bant talked to us about a citizen science project called HOYS-CAPS (Hunting Outbursting Young Stars with the Centre of Astrophysics and Planetary Sciences), which sounded fascinating. Then we finished the night with a frankly terrifying talk by our vice chair Tracey Snelus on 'Microbiology in the Space Environment'. Tracey guided us through the positive research being done in space but reminded us how deadly bacteria can be to space travellers.

With another successful meeting over, chairs put away and dishes washed, I locked up Llanelian Village Hall looking forward to our lecture evening at the end of the month.
www.northwalesastro.co.uk

Jonathen Harty, Chair, North Wales Astronomy Society

at 3am – the householder asleep indoors, the police officer miles away or the burglar sorting out his tools beneath the light?
Bob Mizon, coordinator, the Committee of the Commission for Dark Skies

Thank you Bob. For more information on preventing light pollution see **www.britastro.org/dark-skies** *– **Ed***



▲ The Orion Nebula captured in 73,288 stitches

Cross Stitch Nebula

I thought you might be interested in this rather unique image of the Orion Nebula and the Running Man Nebula created by my wife, Jane. It was hand-stitched by her starting in June 2017 and is based on an image captured by me. The original image has a resolution of 3,032 x 2,016 pixels and a 16-bit colour palette. The hand-stitched version has a resolution of just 216 x 216 cross stitches (18 cross stitches to the inch) and a colour palette of 82 colours. It has a total of 73,288 individual stitches!
Steve Richards, West Sussex

*We're impressed, Jane, both with the artistry and your commitment! – **Ed***

Ain't no mountain

Looking at the pictures in the May issue's Eye on the Sky, I noticed 'A rose in the clouds' and wondered: if Jupiter is a gas giant, why is there what appears to be the top of a mountain? There even appear to be craters on the right-hand side.
Stephen Jessop, via email

*That light, central feature does look rather un-cloudlike doesn't it? But it isn't rock, it's gases from the lower atmosphere that the storm has dredged up. Because Juno's images are small file sizes, there will inevitably be some artefacts and pixelation after they've been processed, giving that rock-like appearance. – **Ed***

Tweets

Sam King
@samking_uk • Apr 23
Horizon – My first capture of the magical aurora from a recent trip to Bamburgh castle. I was delighted to also be able to capture the Milky Way and Andromeda in this image. #Aurora #Nightsky #WexMondays #sharemondays2018 #fsprintmonday @skyatnightmag @B_Ubiquitous @UKNikon

Meanwhile on FACEBOOK...

WE ASKED: What's the most interesting historical astronomical site you've been to?

Gordon Eyton-Williams
Chichen Itza, amazing place!

Peta Bosley
Hoba meteorite in Namibia (a two-day diversion on our holiday).

Mohammed Nouri
Les pyramides de Gizeh.

Steve Green
Goonhilly.

Keith Moseley
Pad 39A at Kennedy Space Center.

Simon Upton
Herstmonceux and Tucson observatory.

Aprill Harper
Mullard Radio Astronomy Observatory – full of astronomical history and fascinating relics.

Paul Beach
The Jantar Mantar ancient observatory in Jaipur, India. It has 19 instruments including the world's largest sundial.

Scott Parker
Stonehenge!

OOPS!
On the map of the Canary Islands in the feature 'The Canaries, islands of astronomy' (page 75, May 2018 issue), we incorrectly labelled the Canaries' most southwesterly island Frontera, instead of El Hierro.

BBC

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Sky at Night MAGAZINE

Hotshots

This month's pick of your very best astrophotos

YOUR BONUS CONTENT

A gallery containing these and more of your stunning images

▲ The Cone Nebula and the Christmas Tree Cluster

IAN J CRICHTON, DALGETY BAY, FIFE, 9 FEBRUARY 2018

Ian says: "The achievement of taking the raw data and processing it through various software packages to produce such stunning images is what makes this hobby so worthwhile. This particular region, around the constellations of Monoceros, the Unicorn, and Orion, the Hunter, is one many astrophotographers enjoy because it is so rich with impressive targets to image."

Equipment: Canon EOS 70D DSLR camera, TS-Optics Imaging Star 130mm apo refractor, Sky-Watcher NEQ6 Pro SynScan mount.

***BBC Sky at Night Magazine* says:** "With minimal star trailing, beautiful wisps of nebulosity and swirling patches of dark dust, Ian's image is this month's deserved winner."

About Ian: "As a young boy I was hooked on astronomy after reading the *Observer's Book of Astronomy*. I bought a pair of 10x50 binoculars, learned all the constellations and luckily got access to a 3-inch refractor. I promised myself that when I retired I would buy the equipment to continue my hobby more seriously. Astrophotography seemed the best way to go after seeing the amazing objects that amateurs could capture. My favourite targets are emission nebulae and reflection nebulae; the shapes and colours can be quite stunning."

◀ The Pinwheel Galaxy

PETE LAWRENCE, LISBURN, COUNTY ANTRIM, 22 MARCH 2018

Pete says: "This target started the night very low in the eastern sky so I struggled with light pollution at first, as this is the direction of two large cities near my home. Quite a few images didn't make the final stack owing to lack of contrast and bad gradients. I was fortunate to have a night and a half of clear sky and little wind – pretty rare for me."

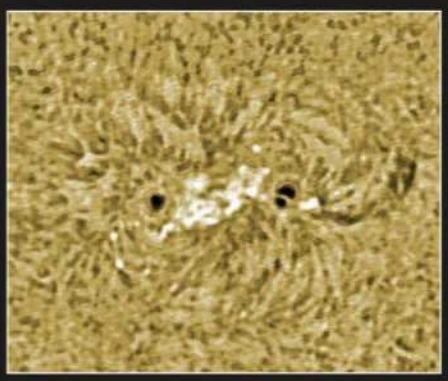
Equipment: Atik 428EX mono CCD camera, Sky-Watcher Quattro f/4 imaging Newtonian, Sky-Watcher NEQ6 Pro SynScan mount.

▼ Open cluster and nebula in Auriga

STEPHEN D PASTOR, MAYHILL, NEW MEXICO, US, NOVEMBER & DECEMBER 2016, JANUARY 2018

Stephen says: "This is open cluster NGC 1931 surrounded by nebula Sharpless 2-237 in Auriga. Faint red hydrogen emissions surround the compact cluster. The image took a total of 15 hours."

Equipment: QSI 683 CCD camera, Takahashi CCA-250 astrograph, Paramount ME mount.



◀ Sunspot 2699

ROGER SAMWORTH, NAILSTONE, WARWICKSHIRE, 11 FEBRUARY 2018

Roger says: "I have my setup indoors sitting on an upstairs windowsill, looking out through the double glazing. This means it is instantly available to take advantage of any holes in the cloud cover. The image is from a 200-frame AVI stacked and wavelet processed with RegiStax 6 and finally processed with GIMP."

Equipment: Bresser MikrOkular Full HD eyepiece camera, Lunt LS35THa h-alpha telescope, Sky-Watcher tabletop EQ1 equatorial mount.

◀ Bode's and the Cigar Galaxies

STACEY DOWNTON, BIRMINGHAM, 8 MARCH 2018

Stacey says: "These were the first objects I imaged when I first set up my scope a few months back. I thought it would be a good way to measure my progress and see how far I've come. I had a couple of difficulties, such as all the satellites running through my image. I decided to leave the trails in to show how many are travelling up there. Because I'm using a light pollution filter I found it difficult to get the correct colour balance."

Equipment: Canon EOS 200D DSLR camera, Sky-Watcher Evostar 80ED DS-Pro refractor, Sky-Watcher EQ5 Pro mount.

▲ The Rosette Nebula

TOM WILDONER, WEATHERLY, PENNSYLVANIA, US, 6 FEBRUARY 2018

Tom says: "This was an early test for my new refractor. I was looking for a nice wide-field deep-sky object and the Rosette was well positioned and fitted the bill. It is large, colourful and also has an embedded open cluster."

Equipment: Canon EOS 6D DSLR camera, Sky-Watcher Esprit 120 ED Pro triplet apo refractor, Celestron CGEM DX mount.

The Pinwheel Galaxy ▶

MARK WEBSTER, MANSFIELD, FEBRUARY & MARCH, 2018

Mark says: "Processing was a bit of a challenge as the seeing conditions haven't been great of late in my area. The images were calibrated and stacked in PixInsight and then processed in both Photoshop and PixInsight."

Equipment: QHY10 CCD camera, Altair 115 f/7 ED triplet apo refractor, AZ EQ6 Go-To mount.

▲ The Horsehead Nebula

SIMON TODD, HAYWARDS HEATH, 9, 11, 15 FEBRUARY 2018

Simon says: "Every year I reimage this with a different technique; this year with a 20mpx, back-illuminated CMOS. Next year I will probably reimage it again in narrowband, but I never grow tired of imaging old Horsey. The main challenge is the extremely bright star Alnitak, which creeps into the left side of the image."

Equipment: QHYCCD 183M CMOS camera, Sky-Watcher Quattro f/4 8-inch imaging Newtonian, Sky-Watcher EQ8 Pro equatorial mount, Starlight Xpress filter wheel.

▼ The Moon

DAVID MOTTERSHEAD, MACCLESFIELD, CHESHIRE, 25 FEBRUARY 2018

David says: "I chose the Moon as it was not full, making for more interesting photos with shadows cast in craters and detail better defined. Although cold, the air was still and the only issue I had was that the Moon was high up, resulting in the camera being at quite an acute angle on the tripod, worrying me that it would tip over!"

Equipment: Nikon D850 DSLR camera, Sigma 500mm lens, tripod.

◀ Zodiacal light and the Milky Way

DANIEL CAMERON, GALLOWAY FOREST DARK SKY PARK, 19 MARCH 2018

Daniel says: "The zodiacal light had eluded me ever since I started doing astrophotography and I am chuffed to have finally managed to capture it. The best time to image it is either in spring not long after sunset or in autumn not long before sunrise. You need a good site free from light pollution, so being in the Galloway Forest Dark Sky Park was the ideal opportunity."

Equipment: Canon EOS 60Da DSLR camera, Samyang 8mm lens, Sky-Watcher Star Adventurer mount.

Mapping the MILKY WAY

Charting over a billion stars is the mission of the Gaia spacecraft, which released its second ream of data on 25 April. As **Benjamin Skuse** finds out, collecting starlight is just the first step in a long journey of discovery

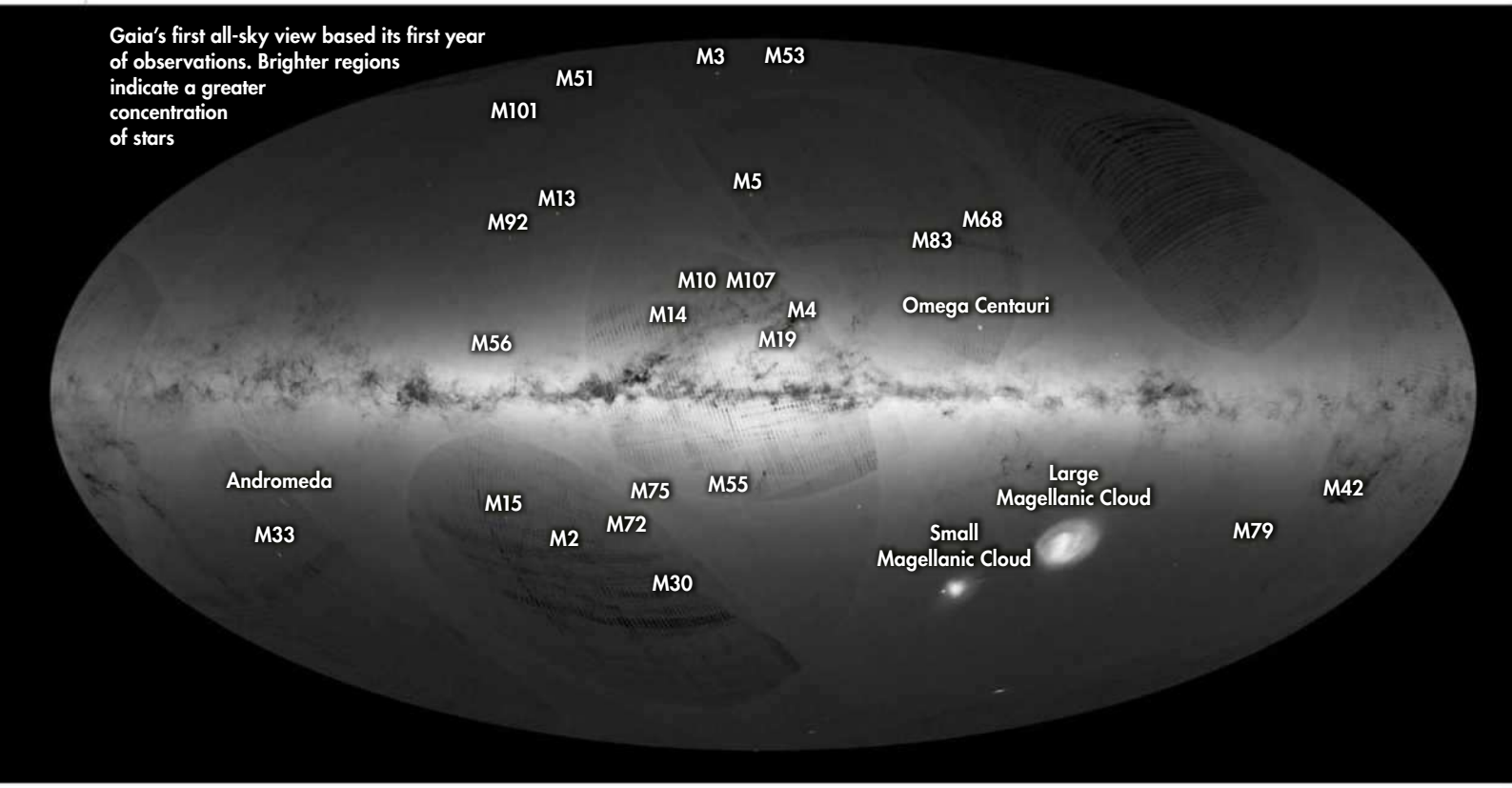
ABOUT THE WRITER
Dr Benjamin Skuse is a mathematician turned science writer based in Bristol, UK

ESA–D. DUCROS/2013

The light from a star on the other side of the Galaxy can glide through space untroubled for tens of thousands of years before it reaches our Solar System, but if it happens to hit one of the electronic light sensors aboard the Gaia space telescope, it begins an epic new journey.

The European Space Agency (ESA)'s Gaia mission launched in 2013. With the express aim of building the largest and most accurate 3D map of stars in the Milky Way to date, the final catalogue will reveal the positions, distances, movements and changes in brightness of more than a billion stars. It will discover hundreds of millions of new stars, tens of thousands of asteroids and thousands of exoplanets – all offering crucial insights into the composition, formation and evolution of our Galactic neighbourhood. As a bonus, thousands of new quasars and supernovae ▸

Gaia's goal is to create the largest, most precise three-dimensional map of our Galaxy by surveying more than a thousand million stars, scanning each around 70 times during the course of its mission



Gaia's first all-sky view based its first year of observations. Brighter regions indicate a greater concentration of stars

ESA/GAIA/DPAC, ESA/GAIA/DPAC/IEEC-UB, ESA X 2

▸ from further afield are also expected to be detected by Gaia's powerful spyglass.

Sweeping and spinning across the sky about 1.5 million km from Earth with two telescopes angled 106.5 degrees from one another, Gaia records a star's position and colour with 102 star-detecting CCDs that make up the spacecraft's billion-pixel camera, marking the precise time of observation by a rubidium atomic clock. This information then joins Gaia's near-continuous data stream fired down to Earth at a few megabytes per second. ESA's three powerful ground stations in Australia, Spain and Argentina pick up Gaia's weak signal and then send it on to the European Space Operations Centre (ESOC) in Darmstadt, Germany.

Extreme data processing

When it reaches ESOC, the data is completely unintelligible because of the specific way in which Gaia scans the sky. As a result, an army of 450 scientists and software experts spread across 20 countries – collectively known as the Gaia Data Processing and Analysis Consortium (DPAC) – are entrusted with the huge and complex task of translating data from the space telescope into scientifically meaningful information.

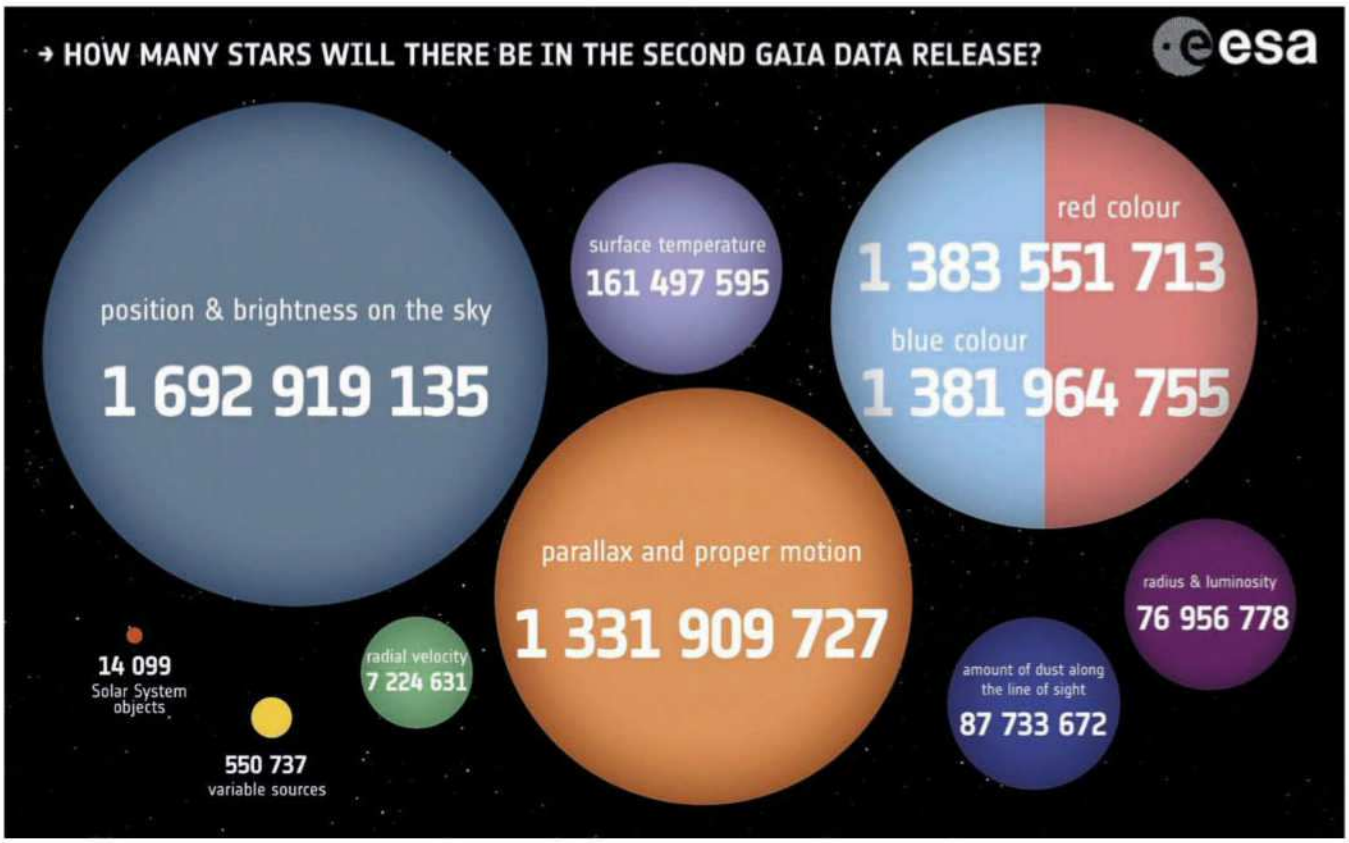
After decompressing, identifying and storing the various data packets at ESOC, the first to get their hands on the data is the European Space Astronomy Centre (ESAC) near Madrid, Spain. This facility performs 'First Look' and 'Initial Data Treatment' processes constantly, which help calibrate the spacecraft and produce vast tables of vital information. These are used to determine where the images were taken, what brightness and colour the objects were, and whether the new observations match previous ones. With Gaia repeatedly scanning the entire sky, the latter step picks up new transient events like supernovae and new Solar System objects like asteroids, producing alerts that can be followed up by ground-based telescopes.

> "The data goes on a whirlwind tour of Europe, stopping off at Gaia's six dedicated data processing centres"

From there, the data goes on a whirlwind tour of Europe, stopping off at Gaia's six dedicated data processing centres, which run state-of-the-art algorithms and software developed by nine coordination units across the continent. Taking

	afSamples[6]	afSamples[7]	afSamples[8]	afSamples[9]	afSamples[10]	afSamples[11]	afSamples[12]	afSamples[13]	afSamples[14]	afSamples[15]	afSamples[16]	afSamples[17]
49	1564	1566	1579	1598	1600	1704	1708	1614	1564	1568	1573	1570
50	1529	1533	1527	1528	1552	1586	1603	1550	1549	1537	1533	1536
51	1473	1475	1471	1510	1578	1527	1489	1472	1473	1471	1472	1468
52	1489	1494	1489	1513	1622	1591	1512	1499	1492	1490	1492	1485
53	1539	1535	1545	1539	1563	1636	1637	1566	1551	1544	1537	1525
54	1654	1663	1657	1658	1691	1770	1740	1671	1661	1666	1655	1655
55	1571	1576	1580	1585	1599	1655	1631	1586	1572	1573	1576	1573
56	1488	1489	1490	1510	1631	1628	1517	1501	1493	1483	1487	1482
57	1758	1758	1757	1764	1782	1846	1847	1787	1762	1757	1756	1753
58	1636	1638	1638	1653	1678	1730	1674	1637	1620	1629	1629	1635

▼ A snapshot of raw data from Gaia's CCD sensors. For every star that Gaia observes, the instruments acquire nine tiny 'images' of just 18x12 pixels. Each column represents one of these pixels and each row corresponds to one star



▲ This infographic released by ESA gives an overview of the sheer amount of information revealed in Gaia's second data release in April

GAIA'S SECOND WIND

Astronomers eagerly await the latest data, but what might this information reveal?

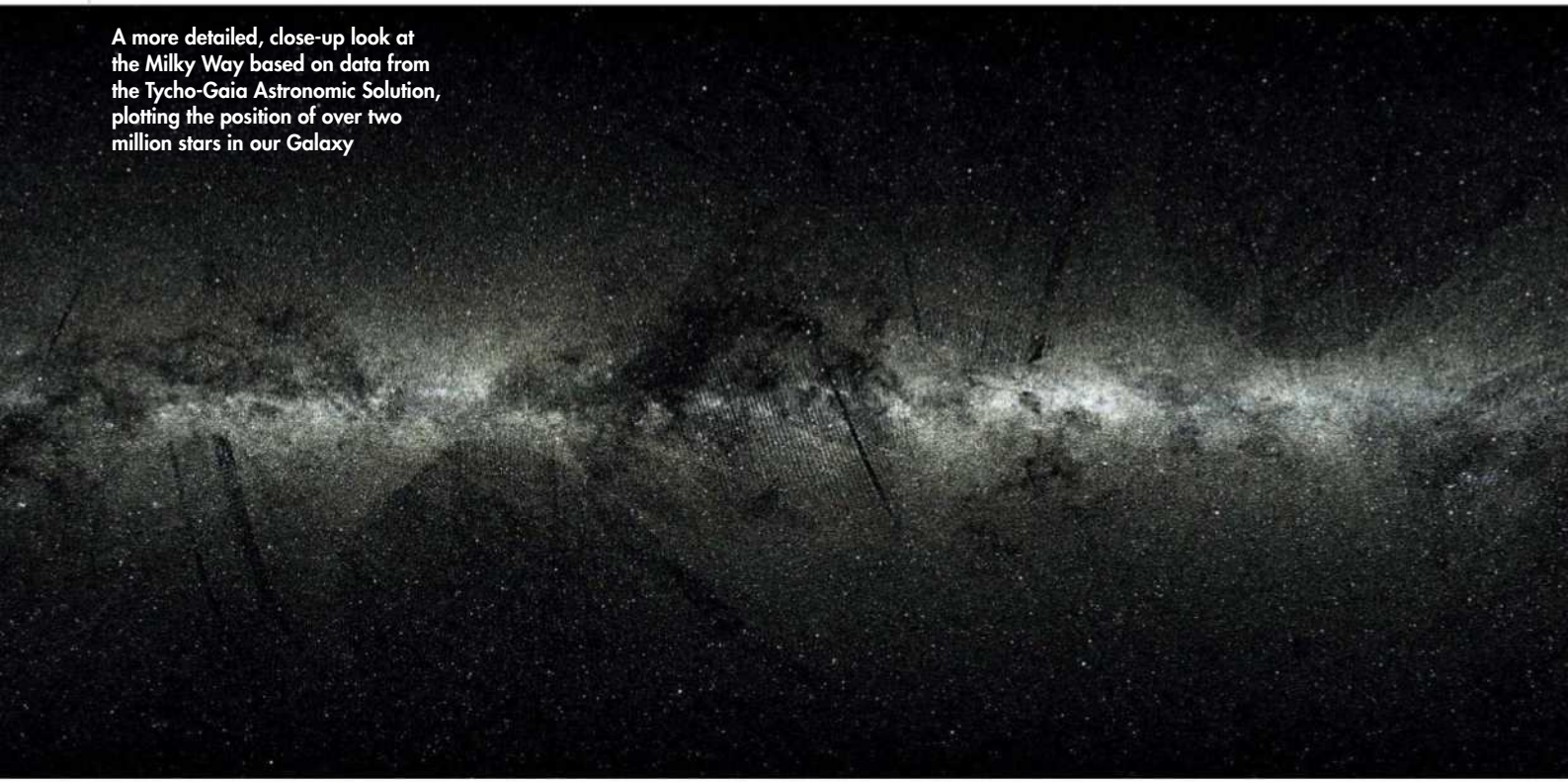
Significantly bigger and better than the first data release, Gaia's second data release contains the position, distance, proper motion, brightness and colour of over 1.3 billion stars, allowing for more detailed studies of the Milky Way's composition, formation and evolution. This data will be enhanced by measurements of the velocity towards or away from Sun, known as 'radial velocity', for six million stars. Combined with distance and proper motion, radial velocity enables the calculation of a star's true stellar motion in space with respect to the Sun and the Milky Way, offering important insights at the Galactic scale.

Meanwhile, the temperature details of 150 million stars will help build a better picture of the nature of the Galaxy's stellar population, while light curves recording the changes in brightness of more than half a million variable stars will hopefully expose new information on these objects, from Cepheid variables, which have played a major part in determining distances to far-away galaxies, to Mira variables, which may shine a light on the fate of our own star, the Sun. Finally, the data release will also detail over 13,000 near-Earth objects such as main-belt asteroids and Trojans, providing new clues about how the Solar System formed.

The European Space Astronomy Centre (ESAC) at Villanueva de la Cañada, near Madrid in Spain, is where Gaia's data is transformed into vast tables of information

a suspected quasar as an example, the Gaia data remains at ESAC or shoots over to Torino, Italy, to determine the exact position, proper motion (shifts in position as observed on the plane of the sky) and distance of the object. At the same time, the suspected quasar's colour and brightness are established in Cambridge. This processed data then travels to Paris and Geneva where complex algorithms assess the object's variability and characteristics in an attempt to deduce its nature.

A further step known as the Intermediate Data Update sends all the data to Barcelona where MareNostrum III, one Europe's most powerful supercomputers, iteratively improves on the Initial Data Treatment. This data is then processed and analysed again by Gaia's data processing facilities for even more accurate results. At the end of this ▸



A more detailed, close-up look at the Milky Way based on data from the Tycho-Gaia Astronomic Solution, plotting the position of over two million stars in our Galaxy

▸ winding path, the fully processed data finally returns to ESAC to be added to the vast Gaia catalogue, which is expected to hold six petabytes – equivalent to over a million DVDs' worth of information – by the end of the mission. But this is far from the end of the story for the data Gaia collects: this is the stage at which analysis can begin.

"A unique aspect of the Gaia mission is that we do not do any science with the data before it is made public," explain Anthony Brown and Antonella Vallenari, chair and deputy chair of the DPAC Executive, respectively. "In principle it is left entirely up to the astronomical community to find all the interesting stuff in our data."

And find stuff they have: within 24 hours of the first data release in September 2016, over 11,000 users had accessed the catalogue, subsequently generating over 230 scientific papers.

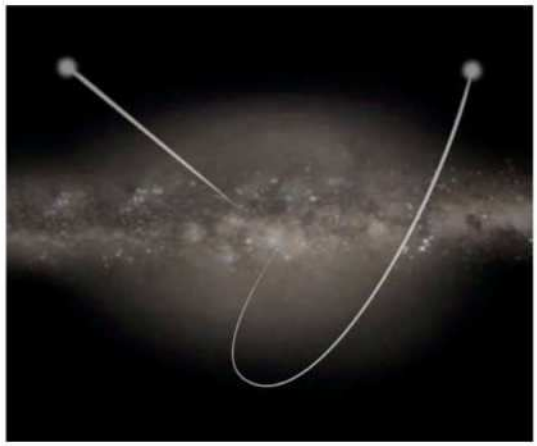
Hypervelocity stars

Alongside a host of insights into our Galaxy, one of the most interesting pieces of work focuses on hypervelocity stars. These stars are thought to result from a binary star coming into contact with the supermassive black hole at the Galactic centre, which kicks one of the pair of stars out at several hundred kilometres per second. Why these stars are important is that their tremendous speed allows them to travel through the whole Milky Way, and this can offer information about how matter – and most intriguingly dark matter – is distributed.

Tomasso Marchetti and colleagues from Leiden University in The Netherlands used the first data release to hunt for these rare runaway gems. But instead of sifting through the data manually – an impossible task – the team turned to advanced data mining techniques. They built an artificial neural network (a computer algorithm that takes inspiration from how the human brain works), which they then trained using millions of simulated hypervelocity stars and normal stars: "The artificial neural network learns from this experience, which allows the algorithm to work on new data and be able to calculate the probability that a new star is a hypervelocity star," explains Marchetti.

"The vast Gaia catalogue is expected to hold six petabytes, equivalent to over a million DVDs' worth of information"

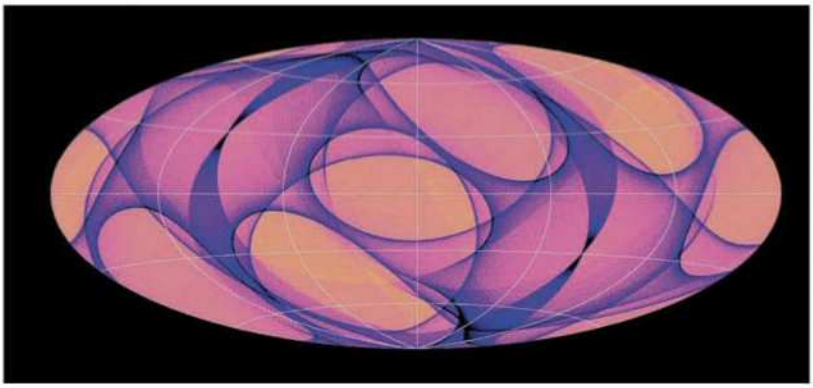
Finding 80 initial candidates in the first Gaia data release, follow-up ground-based observations

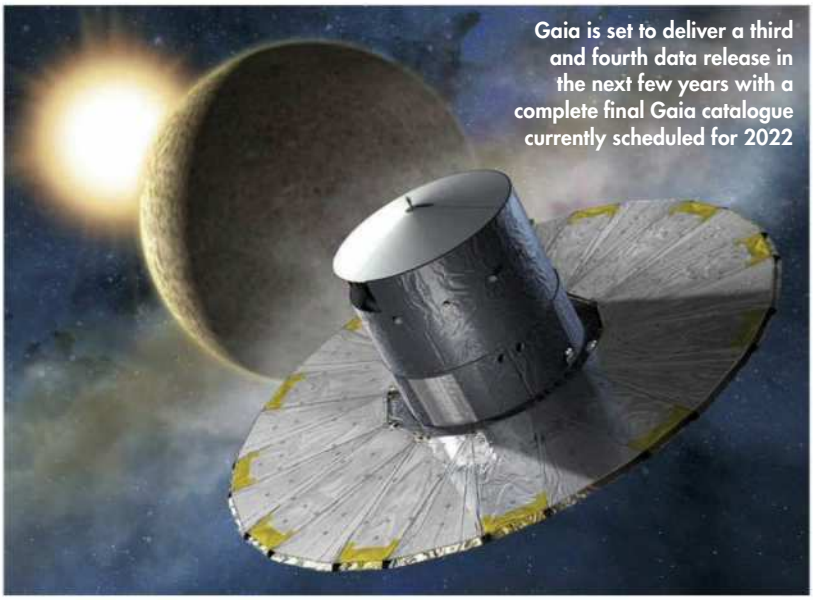


◂ An artist's impression of two hypervelocity stars speeding from the centre of our Galaxy to its outskirts at speeds of several hundred km/s

ESA/GAIA/DPAC, ESA, ISTOCK, ESA–D. DUCROS/2013, ESA/GAIA/DPAC/ACKNOWLEDGEMENT: B. HOLL (UNIVERSITY OF GENEVA/SWITZERLAND) ON BEHALF OF DPAC

▼ Gaia does Spirograph: a graphical representation of how Gaia surveyed the sky in its first 14 months. Darker colours indicate regions that were scanned the most often





Gaia is set to deliver a third and fourth data release in the next few years with a complete final Gaia catalogue currently scheduled for 2022

confirmed six new stars could be added to the roughly 20 previously discovered hypervelocity stars. "Our idea is to use these stars as tracers of the dark matter profile of the Milky Way," says Marchetti. "But in order to do that we need a few hundred hypervelocity stars." Fortunately, the second data release on 25 April is expected to have uncovered at least a few hundred and likely thousands of new runaway stars.

The first release can be likened to a black and white photograph, plotting only the positions of one billion stars plus an estimate of the distance and proper motion for a subset of two million bright stars. Twenty-two months in the making, the second release is more like a 3D DVD blockbuster, revealing detailed information for more than 1.3 billion stars, and 'bonus features' for millions within the sample. The most comprehensive stellar catalogue ever made by some distance, Gaia's second data release is providing astronomers with information to be able to explore the Milky Way like never before.

BBC FOUR

The Sky at Night in May

The team looks through the latest results from Gaia's second data release.

13 May, 10pm on BBC Four (repeated 17 May, 7.30pm) https://bbc.in/1udo2Je

MEASURING THE MOTIONS

Astrometry is the observation of the movement of the stars. The science has come a long way since we first looked up at the night sky

The human eye (~10,000 years ago)
Charting the changing positions of celestial objects through constellations helped ancient farmers across the world keep track of the seasons so that they knew when to plant and harvest their crops.

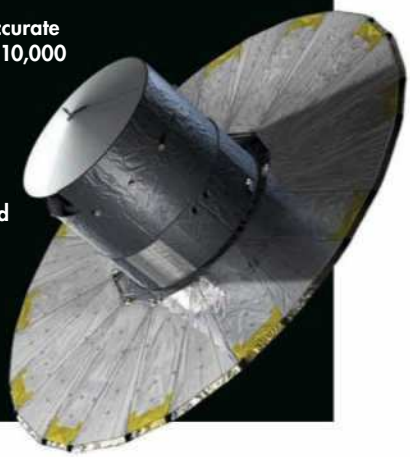
Telescopes (1609)
Revealing countless more stars and offering better positional accuracy than astrometry by eye, telescopes – popularised by Galileo – eventually proved that the planets orbit the Sun.

Parallax (1838)
Friedrich Bessel announced the first measurement of the distance to a star, using 61 Cygni's change in apparent position over a year to deduce a reasonably accurate distance of 10 lightyears.

Astrophotography (1850)
After the first photographic image of the bright star Vega was captured by Harvard astronomers in 1850, astrophotography dominated sky surveys for over a century.

Hipparcos (1997)
In 1995, the last catalogue of stellar parallaxes calculated from ground-based telescopes listed the distances to 8,000 stars. Free from the confounding effects of Earth's atmosphere, ESA's Hipparcos mission compiled a catalogue of 117,955 stars two years later.

Gaia (now)
200 times more accurate and charting over 10,000 more stars than Hipparcos, Gaia signals a new era in astrometry by providing an unprecedented and ever-expanding database of over a billion celestial objects.



The strangest stars in the UNIVERSE

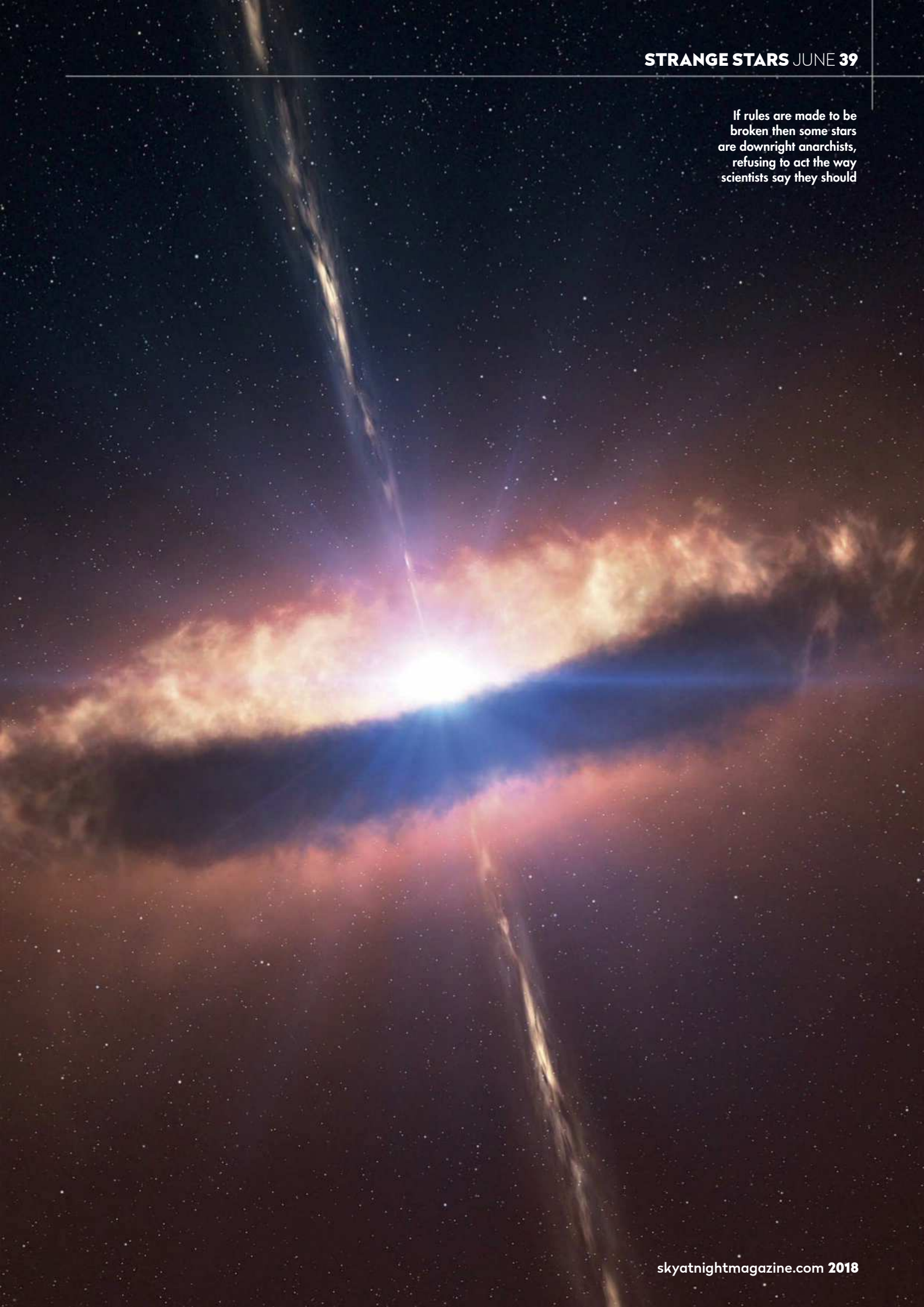
Among the trillion trillion stars in the Universe, there are some real oddballs. **Elizabeth Pearson** looks at some of the weirdest stars astronomers have uncovered in the depths of space

Space has a lot of stars. In the Milky Way alone there are 100 billion, and our Galaxy is just one of 10 trillion. Most of them are perfectly ordinary stars. They spend their lives fusing atoms together to create heat and light, until they run out of fuel and either quietly retire or go out in a blaze of glory as a supernova.

But every so often, astronomers stumble across a star that takes them by surprise. Some are normal stars caught at a turning point in their lives, giving researchers an insight into these important, but often short, periods of stellar life. Others are so unusual that they leave scientists scratching their heads, questioning everything they thought they knew about the stellar life cycle. Here we take a look at eight of these oddballs, quite possibly the strangest stars our Universe has to offer. ▸

ESO/L. CALÇADA/M. KORNMESSER

ABOUT THE WRITER
Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in galactic astronomy at Cardiff University

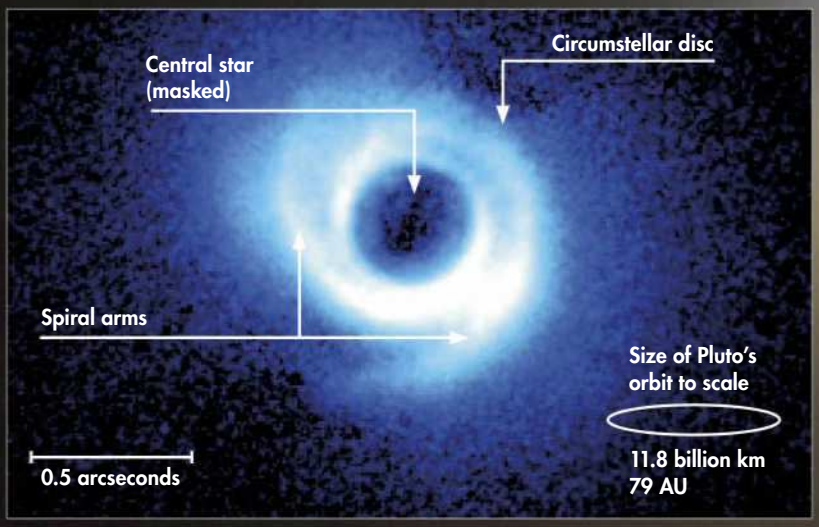


If rules are made to be broken then some stars are downright anarchists, refusing to act the way scientists say they should

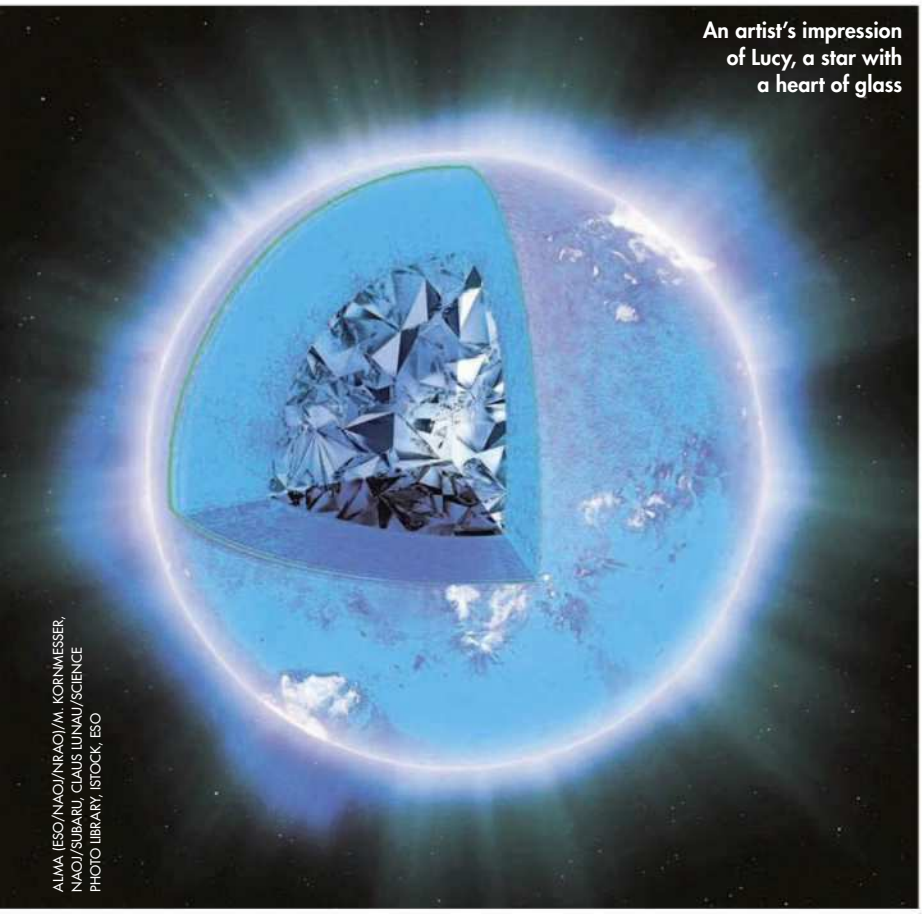
Galaxy or star?

A pair of planets that could easily be mistaken for more

Usually when astronomers see a spiral-arm structure, they're looking at a galaxy, but not so with SAO 206462. The star, located 460 lightyears from Earth, was discovered during an exoplanet search using the Subaru Telescope in Hawaii. But rather than finding fully fledged planets around the young star, astronomers instead discovered planets still in formation. The youthful planets are growing out of a circumstellar disc of gas and dust which extends out to around 80AU, twice the orbit of Pluto. At least two of these planets have shepherded the disc into its unusual shape, with a different planet responsible for each arm.



◂ Star SAO 206462 is being turned into a Catherine wheel by the gravitational forces of two of its planets



An artist's impression of Lucy, a star with a heart of glass

ALMA (ESO/NAOJ/NRAO)/M. KORNMESSER, NAOJ/SUBARU, CLAUS LUNAU/SCIENCE PHOTO LIBRARY, ISTOCK, ESO

Lucy in the sky with DIAMONDS

The vibrations of a white dwarf hint at a secret hidden under the surface

A star in the constellation of Centaurus has a secret at its heart. At first it appeared to be a dim white dwarf, but it subsequently turned out to be incredibly dense with the mass of the Sun crammed into an object only a third the diameter of Earth.

It is also remarkably cool, with a core temperature of a mere 6,600°C (by compaison, the Sun is around 15 million°C). At these temperatures stars begin to vibrate, and astronomers can use these vibrations to peer inside a star. In this case, they found that the star's carbon core had crystallised to form a diamond 10 billion trillion trillion carats in size. The star was later nicknamed Lucy, after the Beatles song 'Lucy in the Sky with Diamonds'.

Since the discovery of Lucy, several other crystallised stars have been found, some with diamond hearts the size of Earth.

Scientists estimate that Vega is about halfway through its life, but that's not the reason for its middle-aged spread

Squashed STAR

Vega is one of the brightest stars in the sky. It also has a spare tyre

The star Vega is a familiar sight to any northern hemisphere astronomer. But if we got to see the bright star from a different angle, we'd have a very different view. Because Vega is squashed!

Vega's bulging waistline – its high oblateness – is caused by a high spin rate: it rotates once every 12.5 hours. This throws material out around its equator. As this stellar material is further from the centre of the star, it experiences less gravity, which causes it to cool and darken – a phenomenon known as gravity darkening. As Vega faces Earth pole-end-on, it still looks round to us, but its dark halo is a tell-tale sign of a cooler equator and oblate shape.

Stellar Wind MACHINE

When WR104 goes supernova, it could cause problems for Earth

There is a giant in our Galaxy, waiting to burst and send a wave of hot gas and radiation towards Earth. That star is WR104.

WR104 is a Wolf-Rayet, a star at the precarious point in its life before it goes supernova. The core has no helium left to burn. Instead WR104 is forced to churn through heavier elements such as oxygen, which upsets the careful balance between gravity and fusion inside it, causing the star to shed its outer layers. When the oxygen finally runs out, which could happen tomorrow or 8,000 years from now, the star will go supernova.

However, this cosmic firework show will be a bit different. WR104 is one half of a binary pair, and the two stars feed into each other, spinning up their stellar winds until they are going incredibly fast. Some scientists think the explosion will align with the axis of spin, which is pointing directly at us.

While we are far enough away that even a directed supernova won't hurt us, there is a potential part of the explosion that could be deadly – a gamma ray burst (GRB). Luckily, it takes a very specific, and unlikely, chain of events for a Wolf-Rayet to create a GRB and even if it does, WR104 might be pointed far enough away to miss us. Even so, astronomers will be keeping a close eye on this 7,800 lightyear distant star. Just in case. ▸

WR104 could explode at any time in the next 8,000 years with some unpredictable cosmic fireworks

It may be better to burn out than fade away but this star wants it both ways

The star that WOULDN'T DIE

A highly unusual supernova that breaks all the rules

"Supernovae – the explosions of stars – all get bright and then fade within a few months," says Iair Arcavi, an observational astronomer from University of California, Santa Barbara. When his team first discovered the stellar burst iPFT14hls in 2014 it was already beginning to fade away.

But then it rose from the dead and brightened once more.

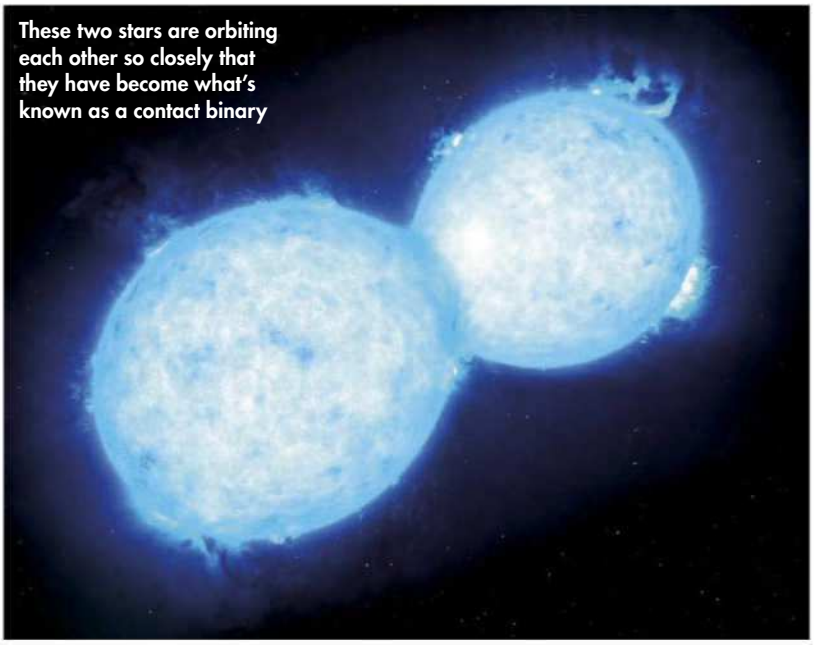
"Zheng Wong, who noticed the brightening, asked me whether that was normal, and I said absolutely not," says Arcavi. "A supernova almost never gets brighter again after having faded. It went on to fade and brighten at least five times in total, deepening the mystery."

The mystery continued to deepen when they measured the supernova's spectrum, the rainbow of light which reveals the velocity, composition and temperature of a star. The supernova was evolving 10 times slower than other stars, meaning that when it looked 60 days old, its actual age was 600 days. It might have been even older, as another supernova had been recorded in the same spot in 1954.

"We've never seen two explosions in the same spot on the sky separated by 60 years before," says Arcavi. "Each of the peculiar properties is hard to explain on its own, and even harder to explain all together. iPTF14hls breaks all the theoretical models of supernova behaviour we have."

There are several suggestions for what's causing the odd behaviour. The supernova could be colliding with surrounding material which then glows, or it could be iPTF14hls is actually a massive star shedding material to hold off its own collapse. But neither solution seems to explain everything.

"We still don't understand how iPTF14hls is possible," says Arcavi.



These two stars are orbiting each other so closely that they have become what's known as a contact binary

ESO/M. KORNMESSER, ESO/L. CALÇADA X 2, NASA/JPL-CALTECH

When two BECOME ONE

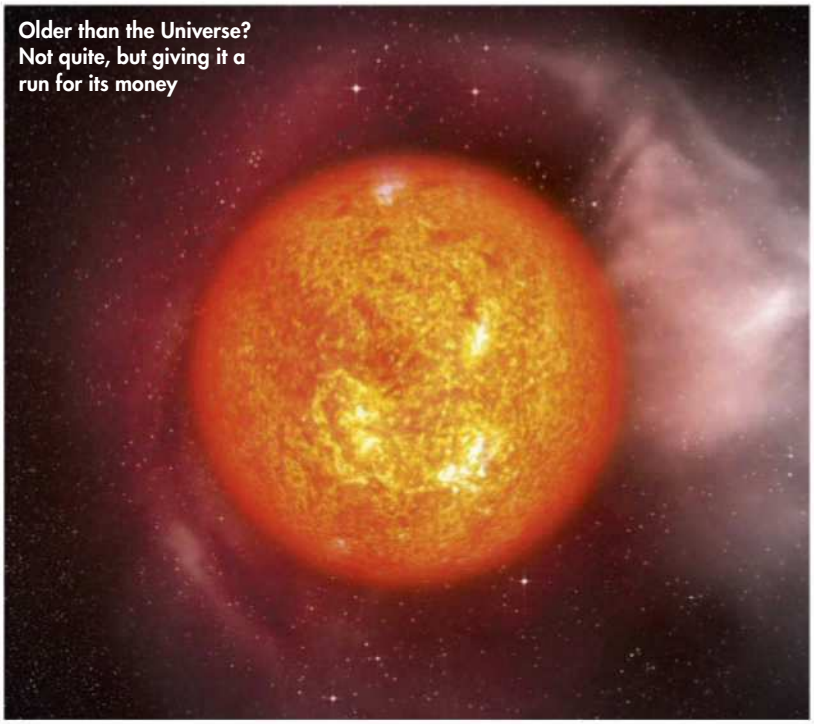
A binary pair that are so close together they can actually touch each other

At first glance, MY Camelopardalis appears to be a fairly common or garden variable star, but on closer inspection astronomers concluded it was a binary pair. The two stars are orbiting each other at over a million km/h, and they are so close that their atmospheres are beginning to interact.

It's thought MY Camelopardalis is the precursor to a stellar merger. Eventually the two stars, which already weigh in at 32 and 38 solar masses individually, will combine into one giant star over 60 masses in size. Astronomers have long hypothesised that this is how super giant stars are made, but the phenomenon has never been seen before.

The star from before the DAWN OF TIME

A sub-giant from an early era of our Universe



Older than the Universe? Not quite, but giving it a run for its money

When HD 140283, a sub-giant star 190 lightyears from Earth, was first studied in the 1950s it posed something of a paradox: it appeared to be 16 billion years old – two billion years older than the Universe itself. Subsequent observations reduced this age to 13.7 billion years, meaning it would have formed only a few hundred million years after the Big Bang.

Its age earned it the nickname Methuselah's Star, after the oldest man in the Bible. The first sign of its geriatric nature was that it contained 250 times less iron than the Sun, suggesting it had formed in a time before the Universe became suffused with heavy elements from supernovae. Most likely it was one of only the second generation of stars, known as Population II stars, and so by studying its chemical composition, astronomers can work out what the Galaxy was like just when it was beginning to form.

Irregular dimming was thought to be the result of a giant alien structure

Something strange is happening around TABBY'S STAR

This star is periodically dimming in a curious way. Is it aliens? Probably not

In 2015, the citizen scientists of the Planet Hunters website found a very unusual exoplanet around the star KIC 8462852.

"This is a star that appears to be typical in every way you look at it, with the exception of its light curve – that's how its brightness changes with time," says Tabitha Boyajian from Louisiana State University, who led the study into this unusual object. "It is characterised by asymmetric, irregular dimming lasting days, weeks, months and sometimes decades."

Not only was the pattern of dimming irregular, but the brightness dropped by as much as 22 per cent, far greater than if a planet had passed in front of it and blocked out the light.

"Pretty much every explanation has been made at this point," says Boyajian. "The dimming could originate on the star's surface, around the star, in interstellar space or even within our own Solar System."

But there was one explanation that captured the public's imagination. Was the star the home of a giant alien structure?

Boyajian led a crowdfunded observing campaign to look at the star, observing across several wavelengths. If there was a solid structure, the dimming would show up as uniform across all wavelengths, but the observations revealed that whatever was obscuring the star, it was at least partly transparent.

"The latest data indicates that the brightness dips are consistent with dust," says Boyajian. "However, it is yet to be determined where this dust is and how it got to be there."

The team will continue to study the star, now nicknamed Tabby's Star after Boyajian, but expect to find a more natural explanation for the star's odd behaviour.

"Just because you don't know what something is, doesn't mean it's aliens," Boyajian pragmatically concludes.

Through the lens of TIME

Discover astronomy's rich history

This summer is the time to uncover the UK's long association with astronomical science. Members of the Society for the History of Astronomy select six places for you to visit

Astronomy is the oldest science known to man. Its history and the stories which lie behind the advancement of our knowledge are both fascinating and exciting. The United Kingdom has often been at the forefront of discoveries in astronomy, with a rich and diverse range of venues that are accessible to the public, many of which have exhibits and displays that commemorate individuals or specific events.

The Royal Observatory Greenwich in southeast London is probably the most widely known venue for astronomy in the UK and a visit there is highly recommended to explore the magnificent instruments and buildings, and to stand astride of the Prime Meridian Line. Venturing much further back in time, many of our ancient sites, such as Stonehenge in Wiltshire and Maeshowe on Mainland, Orkney, were constructed and aligned to bodies in sky. They are amongst the oldest remaining examples of astronomy in our culture.

In this article we highlight six venues of importance to the history of astronomy, where visits will reward the curious of any age. Other sites from around the country can be found within the SHA's Survey of Astronomical History at **https://shasurvey.wordpress.com/**.

ISTOCK X 2, MASPIX/ALAMY STOCK PHOTO

ABOUT THE WRITERS

This article has been prepared by members of the Society for the History of Astronomy (SHA), a body open to anyone with an interest in the history of astronomy. It organises three meetings a year, has a range of printed and electronic publications and maintains a unique library in the centre of Birmingham. https://societyforthehistoryofastronomy.com/

Jodrell Bank Observatory

Macclesfield, SK11 9DL
Open daily 10am-5pm; check website for dates when closed
Adult £7.30, Child £5.40, Family £17-£28
www.jodrellbank.net

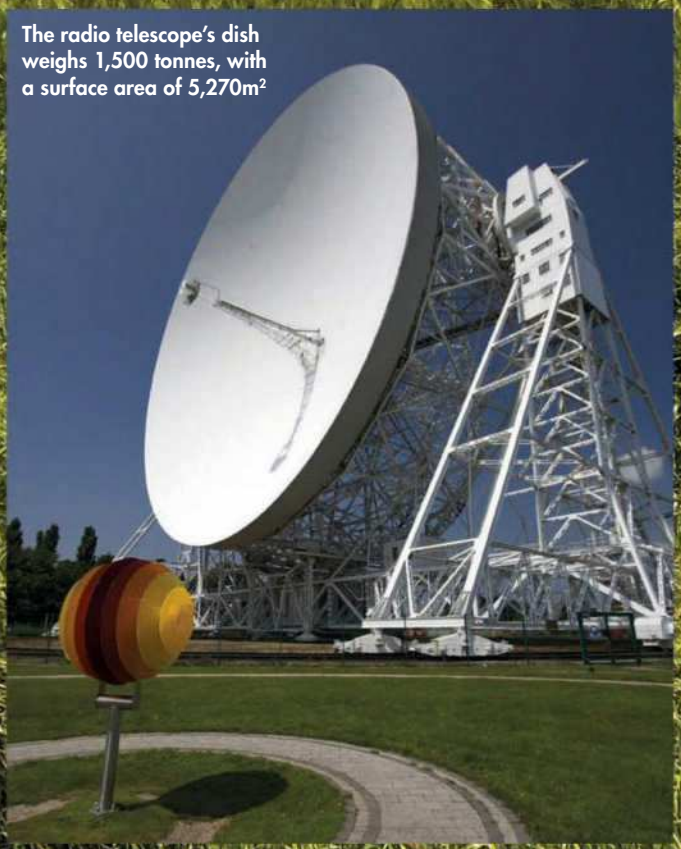
The birthplace of British radio astronomy is situated just 30km south of Manchester. Jodrell Bank's history began in December 1945 when Sir Bernard Lovell utilised surplus World War II radar equipment to study cosmic rays. The early, primitive radio telescopes were replaced by the now famous Lovell Telescope (previously known as the 250 Foot Telescope and then the Mark I Telescope), which, when completed in 1957, was the largest steerable-dish radio telescope in the world. Today it is still the third largest, and is a striking feature of the Cheshire landscape. Jodrell Bank played a crucial role in tracking early space probes, and still operates at the cutting edge of radio astronomy.

An indoor science centre displays fun and informative exhibits and a footpath encourages people to walk around the base of the enormous Lovell Telescope. Further models and displays outside offer visitors more opportunities to learn about the history and science of radio astronomy.

Throughout the year the venue hosts a number of specialist lectures and other events, which will appeal to astronomers whatever their expertise.

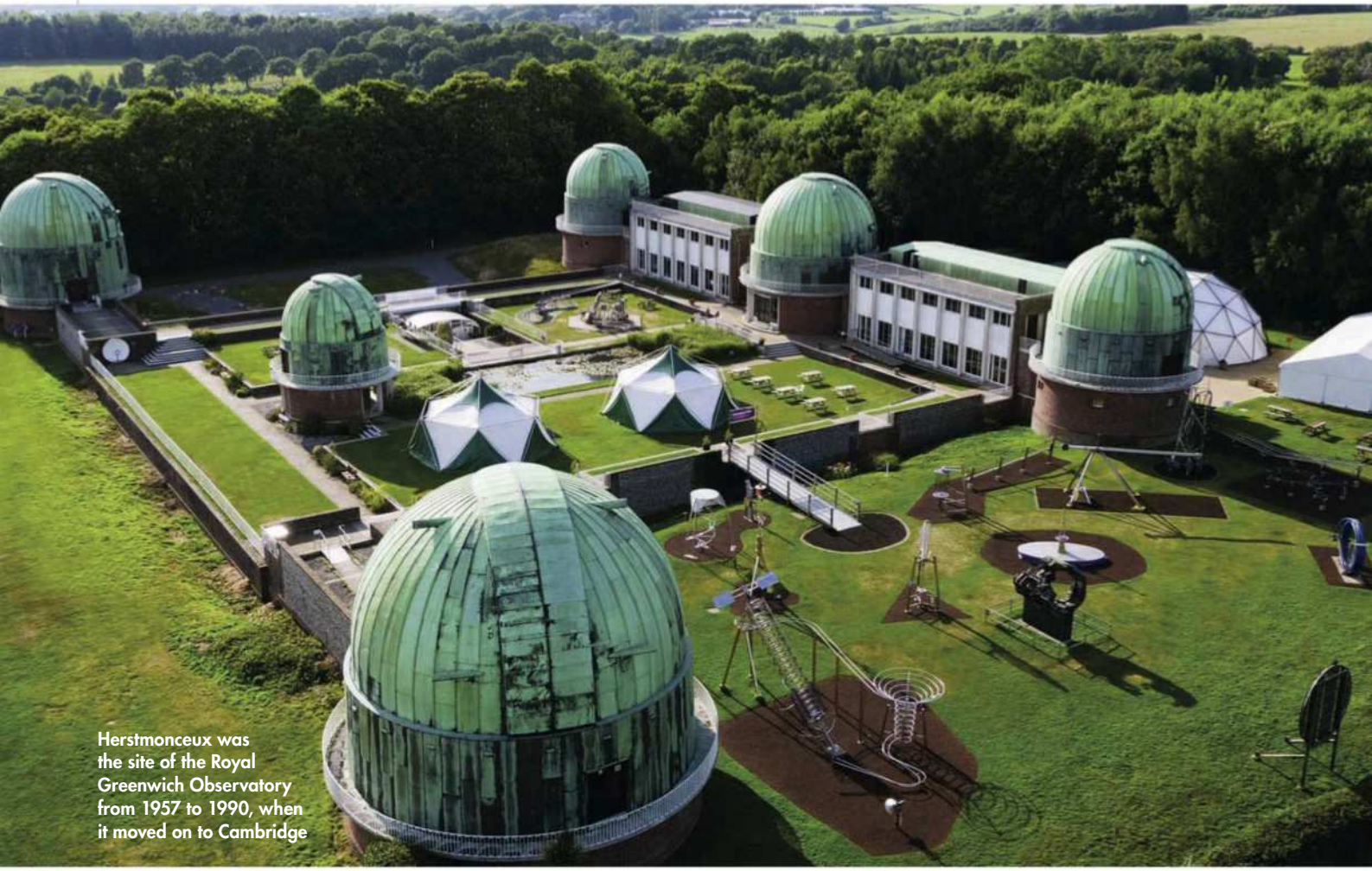
Gerard Gilligan

◂ **Attractions at Jodrell Bank include the largest clockwork orrery in the world, housed in the Planet Pavilion**



The radio telescope's dish weighs 1,500 tonnes, with a surface area of 5,270m²

In the Space Pavilion visitors discover how radio telescopes are used to explore the Universe



Herstmonceux was the site of the Royal Greenwich Observatory from 1957 to 1990, when it moved on to Cambridge

The Observatory Science Centre, Herstmonceux

East Sussex, BN27 1RN
2 Jan-2 Dec (in 2018); 10am-5pm in winter, 10am-6pm in summer
Adult £8.25, Child £6.25, Family £25.70-£29.30
www.the-observatory.org

When the Greenwich Observatory could no longer be used for astronomical work owing to London's light and air pollution in the 1940s, the Royal Observatory was relocated to Herstmonceux, near Hastings.

Herstmonceux Castle dates from the 1440s. The adjacent observatory, finished in 1957, consists of the 'Equatorial Group' of six copper-clad domes that house the Thompson 30-inch reflector (1896), the Thompson 26-inch refractor (1896) and the Yapp 36-inch reflector (1932). The 98-inch (2.5m) Isaac Newton Telescope (1967) was transferred to the Canary Islands in the early 1980s, though the original mirror is still displayed at Herstmonceux.

Open daily, the castle offers a number of outdoor and indoor exhibits that appeal to all ages, and three of the six domes are open during the day. On open evenings and themed evenings two of the other domes are made accessible to visitors. A number of amateur astronomy courses are also offered by the venue.

Bill Barton

▲ Herstmonceux Castle, an impressive Tudor mansion, is well worth a look around too

CHARLIE DAVIS, ISTOCK, DESIGN PICS INC/ALAMY STOCK PHOTO, JAMES KING-HOLMES/ALAMY STOCK PHOTO, BATH PRESERVATION TRUST

Armagh Observatory

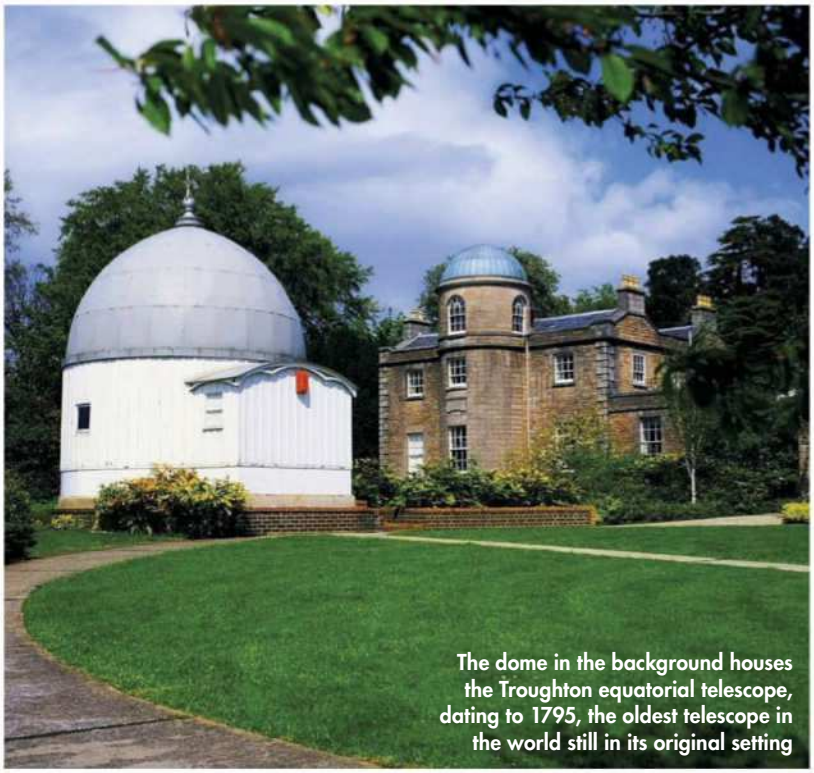
Armagh, BT61 9DG
Astropark open to the public during daylight hours every day
For the planetarium: Adult £6, Child £5, Family £20
star.arm.ac.uk

Armagh Observatory is the oldest scientific institution in Northern Ireland. Since 1789 it has been at the forefront of astronomy research in Ireland. The historic observatory houses a large number of important and unique scientific instruments, including a magnificent Troughton Equatorial Telescope, which was used to record the position of stars from 1795. The modern astronomical centre researches solar astrophysics, stellar activity and much more.

Located to the north of the city of Armagh, the observatory is set in 14 acres of historic grounds that form an 'Astropark'. The park is open to the public all year round and is home to a number of space-themed features including a scale model of the Universe and a stone calendar. Next door is a planetarium, which has shows throughout the day from Monday to Saturday.

While the main building is not generally open to the public, you can take a virtual tour of the historic interior online (**star.arm.ac.uk/virtualvisit/**) or look at many of the other instruments housed there (**star.arm.ac.uk/history/index.html**). Interested groups can contact the observatory to arrange a physical tour.

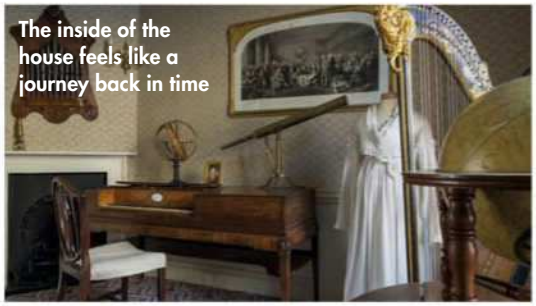
Carolyn Kennett



The dome in the background houses the Troughton equatorial telescope, dating to 1795, the oldest telescope in the world still in its original setting

The Herschel Museum of Astronomy

▲ **The garden is small but beautifully designed along Georgian lines with some surprises**



The inside of the house feels like a journey back in time

Bath, BA1 2BL
Open daily, 1pm-5pm weekdays, 10am-5pm weekends
Adult £6.50, Child £3.20, Family £15.50
herschelmuseum.org.uk

William Herschel is best known for discovering the planet Uranus in 1781, which he did from his garden in Bath, using a 7-inch telescope. It brought Herschel fame and a knighthood from George III who made him the King's Astronomer.

Herschel was born in Germany but moved to England in 1757 intending to follow a musical career. He became interested in optics and making mirrors, which back then were made of speculum metal and required extensive grinding and polishing. William's sister, Caroline, joined him in 1772. Subsequently she became a respected observational astronomer in her own right.

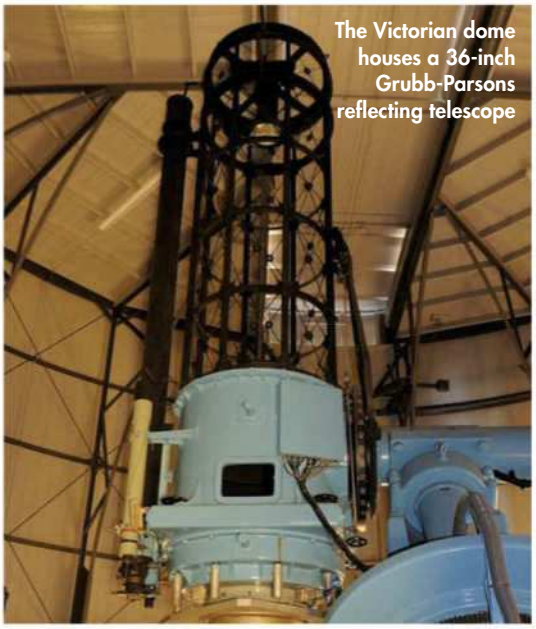
In addition to the discovery of Uranus, Herschel also calculated a more accurate rotational period of Mars and discovered two moons of both Uranus (Titania and Oberon) and Saturn (Enceladus and Mimas).

The Herschel Museum is located in the very house where William discovered Uranus. It is furnished in the style of the time, with displays offering an insight into the life and work of both William and Caroline.

John Chuter

The Royal Observatory Edinburgh


The observatory is a prominent feature on the skyline south of Edinburgh


The Victorian dome houses a 36-inch Grubb-Parsons reflecting telescope

Edinburgh, EH9 3HJ
Group and school visits during weekdays. Special programmes for particular interest groups can be arranged on request
Public astronomy evenings: Adult £5, Child £4. Astronomy talks: Adults £4, Child £2
www.roe.ac.uk

The Royal Observatory Edinburgh (ROE) was first established at Calton Hill during George IV's visit in 1822.

The observatory moved to its present spectacular site, 5km south of the city centre near the summit of Blackford Hill, in 1896. In the following years, the ROE became pre-eminent in astrophysics. In the 1950s it became a world leader in the automated analysis of Schmidt telescope photographic plates. It currently manages three major telescopes in Australia and Hawaii. Housed on-site is the Crawford Collection, one of the greatest collections of astronomical books in the world.

The observatory's public outreach programme includes astronomy talks every Monday evening from October to March, and public astronomy evenings on a Friday. The latter includes a tour of the Victorian telescope dome housing the 36-inch Grubb-Parsons reflecting telescope, stargazing outside (weather permitting) and an opportunity to find out about the work of the observatory.

Bob Bower

Woolsthorpe Manor


The house where Isaac Newton was born on 4 January 1643


On the table is a replica of the first reflecting telescope Newton built


The kitchen where lots of apple pie was made, presumably

Near Grantham, NG33 5PD
16 Feb-28 Oct, open daily except Tuesdays; generally 11am-5pm but check website
Adult £7.70, Child £3.85, Family £19.09
www.nationaltrust.org.uk/woolsthorpe-manor

Woolsthorpe Manor in Lincolnshire is the birthplace of the natural philosopher Sir Isaac Newton (1643-1727). Shortly after Newton graduated from Cambridge University in 1665, the University was closed as a precaution against the Great Plague and Newton returned to his home. During the next 18 months he continued his studies on light and optics, including the famous experiment in which he passed a beam of sunlight through a prism to split white light into its constituent colours.

Visitors can explore inside the 17th century Manor House and an adjacent Science Centre has various hands-on exhibits relating to Newton's work for visitors of any age. In the garden outside is the 400-year-old apple tree which Newton himself said inspired his theory of gravitation.

Within walking distance is Colsterworth Parish Church, where Newton was baptised. Inside the church, on the wall in a small gangway at the rear of the organ, is a sundial made by Newton as a boy. The sundial was formerly at Woolsthorpe Manor, but moved to the church in 1877.

Mike Leggett

The Sky Guide June

June may not provide much in the way of dark sky time but there's still plenty to see, including the ethereal beauty of noctilucent cloud displays

PETE LAWRENCE

ABOUT THE WRITERS

Pete Lawrence is an astronomer and astro imager, and presents *The Sky at Night* monthly on BBC Four

Stephen Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 60

RED LIGHT FRIENDLY

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

DON'T MISS...

- ✦ Saturn's close encounter with the Moon
- ✦ Dazzling Venus near the crescent Moon
- ✦ Saturn at opposition, looking at its best all year

JUNE **HIGHLIGHTS**

Your guide to the night sky this month

ALL MONTH

June and July are the best months to look out for elusive noctilucent cloud (NLC) displays

FRIDAY 1

The 94%-lit waning gibbous Moon can be spotted 51 arcminutes to the north of Saturn at 01:07 BST (00:07 UT).

SUNDAY 3

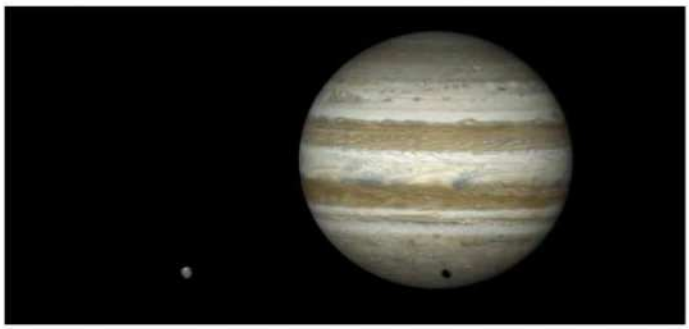
The waning gibbous Moon and bright planet Mars appear close this and tomorrow morning. Look for them low in the southeast around 02:00 BST (01:00 UT).

FRIDAY 15 ▶

One summer treat that you shouldn't overlook is the beautiful double star Albireo (Beta (β) Cygni) which sits at the bottom of the giant Northern Cross asterism in Cygnus, the Swan. A telescope reveals the yellow primary and azure blue secondary star.

MONDAY 18 ▶

Today is a good opportunity to view Ganymede's shadow transiting Jupiter's disc. The process begins at 22:00 BST (21:00 UT) and concludes at 23:50 BST (22:50 UT).



WEDNESDAY 20

The lighting effect known as the Lunar X reaches its peak at 20:35 BST (19:35 UT) which, as this is June, means the Sun will still be up. While this will make spotting the X a little more challenging than usual, it should still be possible.

FRIDAY 22

This is a good time to start looking at Saturn to try to see whether you can spot its rings slowly beginning to brighten as a result of the opposition, or Seeliger, effect. Read more about this on page 53.

SATURDAY 23

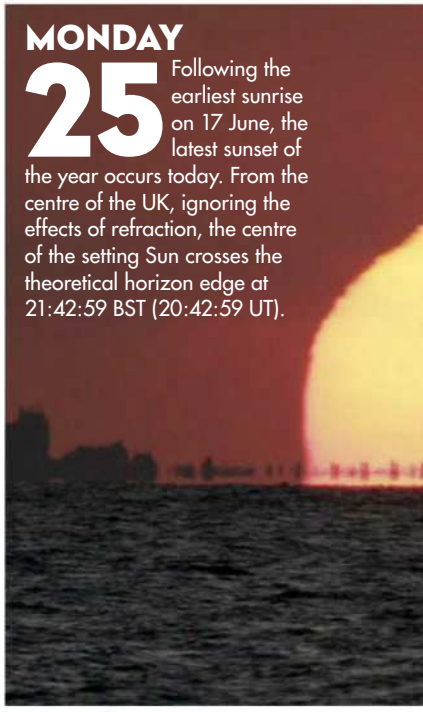
The 83%-lit waxing gibbous Moon and the bright planet Jupiter will appear 3.25° apart this evening at around 23:45 BST (22:45 UT).

SUNDAY 24

The elusive planet Mercury may just about be visible low in the northwest 50 minutes after sunset. At this time it will lie close to the twin stars of Gemini, Castor and Pollux.

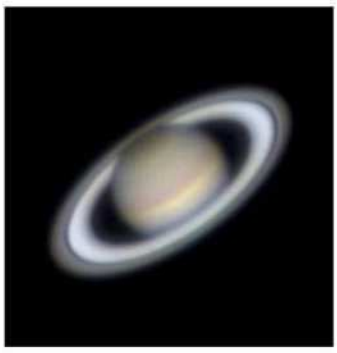
MONDAY 25

Following the earliest sunrise on 17 June, the latest sunset of the year occurs today. From the centre of the UK, ignoring the effects of refraction, the centre of the setting Sun crosses the theoretical horizon edge at 21:42:59 BST (20:42:59 UT).



WEDNESDAY 27 ▶

The planet Saturn is at opposition and is at its biggest and brightest for the year.



THURSDAY 28

In the very early hours, Saturn appears just 1.25° from this morning's full Moon.

PETE LAWRENCE X 8

MONDAY ▶ 11

The Moon is currently out of the way, so despite the sky never truly getting dark, this is a great time to look for star clusters such as the spectacular Wild Duck open cluster, M11. This sits between Aquila, the Eagle and Scutum, the Shield.

SATURDAY 16

At 13:00 BST (12:00 UT), there's a great opportunity to spot Venus during the day as it sits 3° north of a 10%-lit waxing crescent Moon.

Later in the evening, the now 13%-lit waxing crescent Moon and mag. –3.9 Venus appear 6.25° apart in evening twilight.

SUNDAY 17

Today's sunrise is the earliest one for 2018. From the centre of the UK, ignoring the effects of refraction, the centre of the rising Sun crosses the theoretical horizon edge at precisely 04:40:40 BST (03:40:40 UT).

THURSDAY 21

The Sun reaches its most northerly position in the sky at 11:07 BST (10:07 UT) this evening. This is known as the northern hemisphere's summer solstice. It also marks the day of the year when the northern hemisphere's night sky lasts for the shortest time.

◀ TUESDAY 26

Mars reaches mag. –2.0 today making it a dominant object in what is technically the morning sky. It sits in the constellation of Capricornus, the Sea Goat, and thanks to its current brightness and distinctly salmon-pink colour, it's difficult to miss.

FAMILY STARGAZING – ALL MONTH

June and July are the best months in the northern hemisphere for noctilucent clouds (NLCs). The best time to look for them is 90-120 minutes after sunset low above the northwest horizon, or a similar time before sunrise low above the northeast horizon. There's no guarantee of a display but that's all part of the fun; encouraging young observers to look for NLCs can add real suspense and anticipation. Expect lots of disappointment, but it takes just one sighting to turn all that around. There's more information on pages 64 and 72.

www.bbc.co.uk/cbeebies/shows/stargazing

NEED TO KNOW

The terms and symbols used in *The Sky Guide*

UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (RIGHT ASCENSION) AND DEC. (DECLINATION)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'.

FAMILY FRIENDLY
Objects marked with this icon are perfect for showing to children

NAKED EYE
Allow 20 minutes for your eyes to become dark-adapted

PHOTO OPPORTUNITY
Use a CCD, planetary camera or standard DSLR

BINOCULARS
10x50 recommended

SMALL/ MEDIUM SCOPE
Reflector/SCT under 6 inches, refractor under 4 inches

LARGE SCOPE
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing a scope.

THE BIG **THREE**

The three top sights to observe or image this month

DON'T **MISS**

The June Sun

WHEN: A year-long project as specified

June and July, on paper at least, have the potential to be glorious months in the UK because the Sun reaches its highest point marked by the summer solstice. In 2018, this occurs on 21 June at 11:07 BST (10:07 UT). At this time, the Sun's motion in declination against the background stars changes from northbound to southbound. At the precise moment of crossover, the rate of change in declination reaches zero. Indeed, the term solstice comes from the Latin 'sol sistere' meaning 'stationary Sun'.

The Sun's declination at the solstice is equivalent to the obliquity of the ecliptic or the axial tilt of the Earth, which in 2018 is 26.4369°. After the June solstice the Sun's declination decreases as the Sun moves south. The rate of change slowly picks up pace, peaking with the September equinox when the Sun's centre crosses the celestial equator. The rate then slows again, reaching zero at the December solstice. After this the Sun's apparent motion returns northward, accelerating towards the March equinox before decelerating towards the next June solstice. And so the cycle continues…

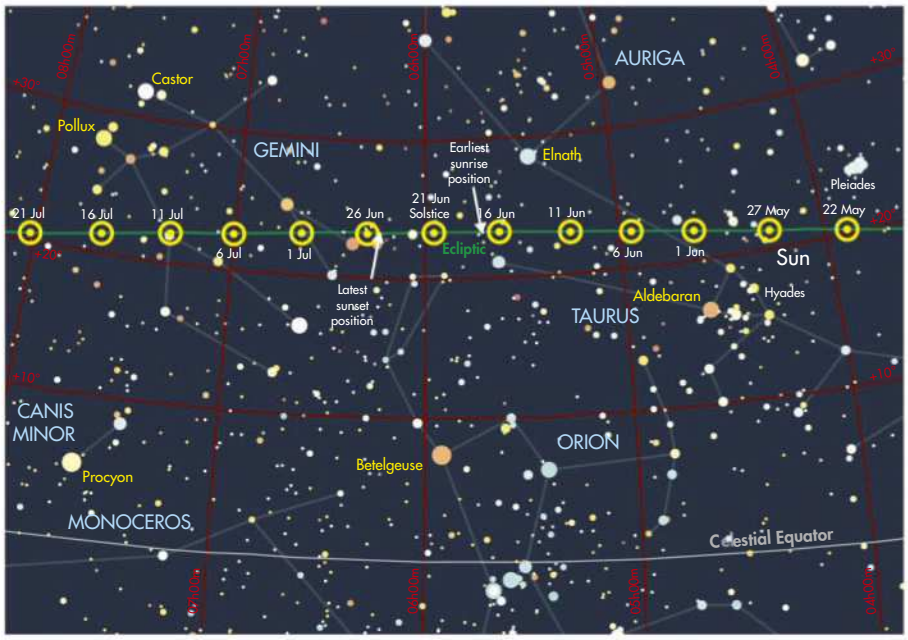
The Earth's motion around the Sun is not at a constant speed because our orbit is elliptical. Our fastest motion occurs at perihelion, the point in Earth's orbit when we are closest to the Sun. This year we reached perihelion on 3 January at 12:34 UT. The slowest motion occurs when we're furthest from the Sun at aphelion. This will occur on July 6 at 13:46 BST (12:46 UT).

The effect of this speed variation causes the Sun's position, measured at the same time of day throughout the year, to describe a 'bowling pin' shape known as the solar analemma.

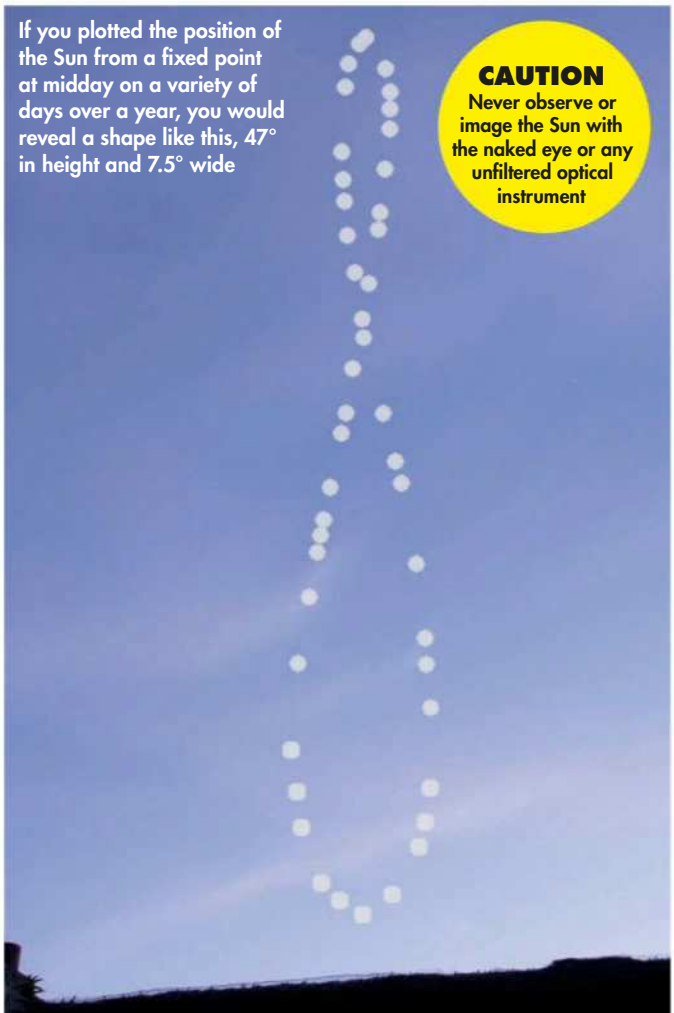
If you're up for a long-term project, you can reveal the analemma by plotting where the end of a fixed, standing stick's shadow falls at the same time of day, every day through the course of a year. Even allowing for missing out days through weather, holidays, illness or plain laziness, you will still see the general shape emerging.

As the variation in orbital speed isn't synced with the Sun's apparent north-south movement cycle, asymmetries occur. June, for example, sees the earliest sunrise and latest sunset. However, the natural asymmetries surrounding the analemma mean the earliest sunrise occurs on 17 June and latest sunset on 25 June.

So as well as presenting a fantastic opportunity for general solar observations from the UK, the high Sun at the June solstice can also be used as a starting point for an interesting project to reveal the nature of our annual motion around the Sun.



▲ **On 21 June the Sun's apparent motion against the stars changes from northbound to southbound**



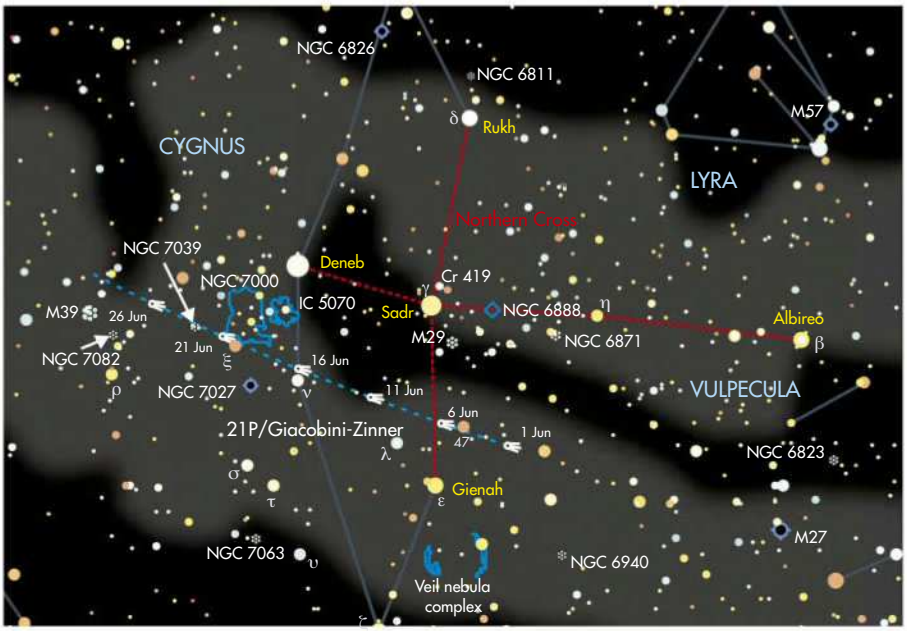
If you plotted the position of the Sun from a fixed point at midday on a variety of days over a year, you would reveal a shape like this, 47° in height and 7.5° wide

CAUTION
Never observe or image the Sun with the naked eye or any unfiltered optical instrument

PETE LAWRENCE X 4

Comet 21P/Giacobini-Zinner

WHEN: Throughout June, as described



▲ 21P/Giacobini-Zinner's June trek. Positions correct for 01:00 BST (00:00 UT) on dates shown

Dim comet 21P/Giacobini-Zinner continues to be well-positioned for the UK, and this month it will be brightening.

On 1 June it appears as a mag. +12.7 object located south of the eastern wing of Cygnus, the Swan. It'll be passing approximately 5° to the west of the Veil Nebula complex during the first few nights of June. Over the coming nights, the comet tracks north, crossing the line joining Sadr (Gamma (γ) Cygni) to Gienah (Epsilon (ε) Cygni) on the night of 6/7 June. Between 15-16 June, it passes 0.5° west of mag. +3.9 Nu (ν) Cygnii *en route* to an encounter with the North America Nebula, NGC 7000.

NGC 7000 covers 120x100 arcminutes of sky. As a result, 21P's northward journey requires several days for it to fully pass the nebula. It'll be in the general vicinity from 16-23 June, passing the mag. +7.6 open cluster NGC 7039 on the night of 22/23 June. This should provide some great astrophotographic opportunities, the green hue of the comet contrasting well with the reddish tones of the h-alpha emission from NGC 7000. At this time 21P/Giacobini-Zinner should be around 11th magnitude.

On the morning of 23 June, the comet clips the edge of the mag. +7.6 open cluster NGC 7039. It passes less than 2° west-northwest of the mag. +7.2 open cluster NGC 7082 and mag. +4.6 open cluster M39, at the end of the month. Its close passage to these two deep-sky objects presents another good opportunity for locating the comet visually as well as setting the stage for some interesting astrophotography. At the end of June, the comet is expected to reach mag. +10.7.

Saturn and the Seeliger effect

WHEN: 13 June – 11 July, around 01:00 BST (00:00 UT)

Saturn reaches opposition on 27 June, a date when it will be in the opposite part of the sky to the Sun. All superior planets except Mars reach opposition at some time throughout the year. At such times Earth and the planet at opposition are closest for the year.

As the respective orbits are elliptical, some oppositions are better presented than others. For Mars, the difference is particularly marked with its perihelic oppositions presenting a much closer view of the planet than its aphelic ones. For Jupiter, the gas giant's greater distance means the opposition difference, although there, is not as dramatic as seen with Mars.

Saturn, being further away still, should, in theory, show less of an improvement than Jupiter. However, Saturn's rings provide an opposition boost, becoming noticeably brighter in the days just before and after opposition. This is due to a phenomenon known as the Seeliger, or opposition, effect. It occurs because when Saturn is at opposition – and Earth is in a direct line with the light streaming from the Sun to Saturn – we cannot see the ring particles' shadows because they're falling directly behind them; we just see the bright faces of the particles themselves. Usually those shadows are in view because the Earth-Saturn-Sun angle is less than 180°.

It's a trick of the light! With Saturn in opposition (bottom) its rings appear to glow more brightly

THE NORTHERN HEMISPHERE IN JUNE

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

- COMPASS AND FIELD OF VIEW

MILKY WAY

WHEN TO USE THIS CHART

1 JUNE AT 01:00 BST
15 JUNE AT 00:00 BST
30 JUNE AT 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

HOW TO USE THIS CHART

1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.

SUNRISE/SUNSET IN JUNE*

DATE	SUNRISE	SUNSET
1 Jun 2018	04:48 BST	21:28 BST
11 Jun 2018	04:42 BST	21:38 BST
21 Jun 2018	04:41 BST	21:43 BST
01 Jul 2018	04:46 BST	21:42 BST

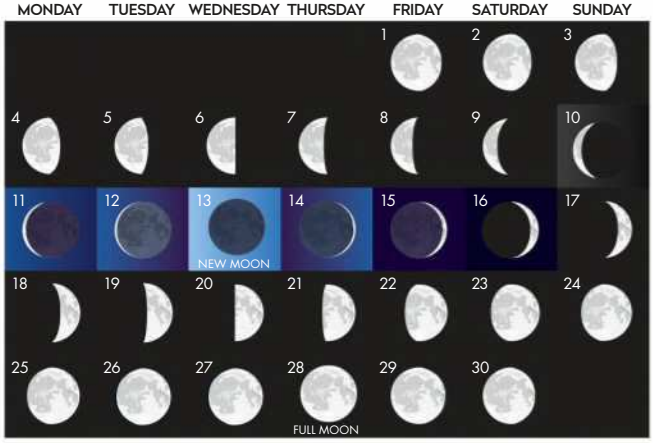
MOONRISE IN JUNE*

MOONRISE TIMES

01 Jun 2018, 23:50 BST	17 Jun 2018, 09:03 BST
05 Jun 2018, 01:31 BST	21 Jun 2018, 14:16 BST
09 Jun 2018, 02:57 BST	25 Jun 2018, 18:57 BST
13 Jun 2018, 04:48 BST	29 Jun 2018, 22:30 BST

*Times correct for the centre of the UK

LUNAR PHASES IN JUNE



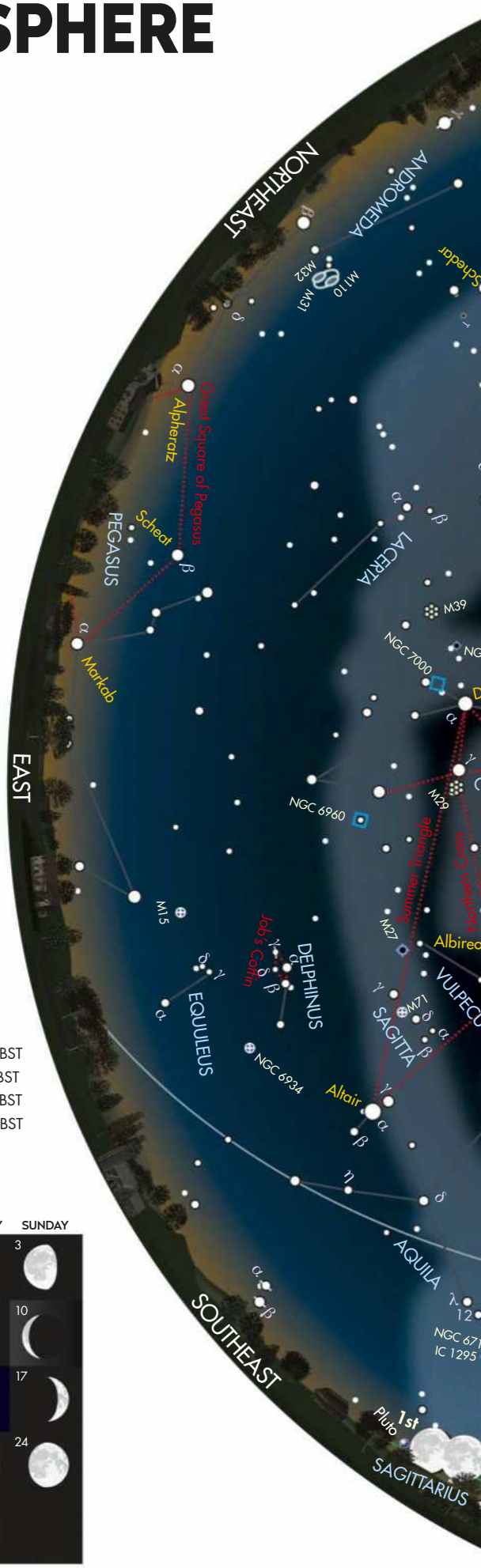
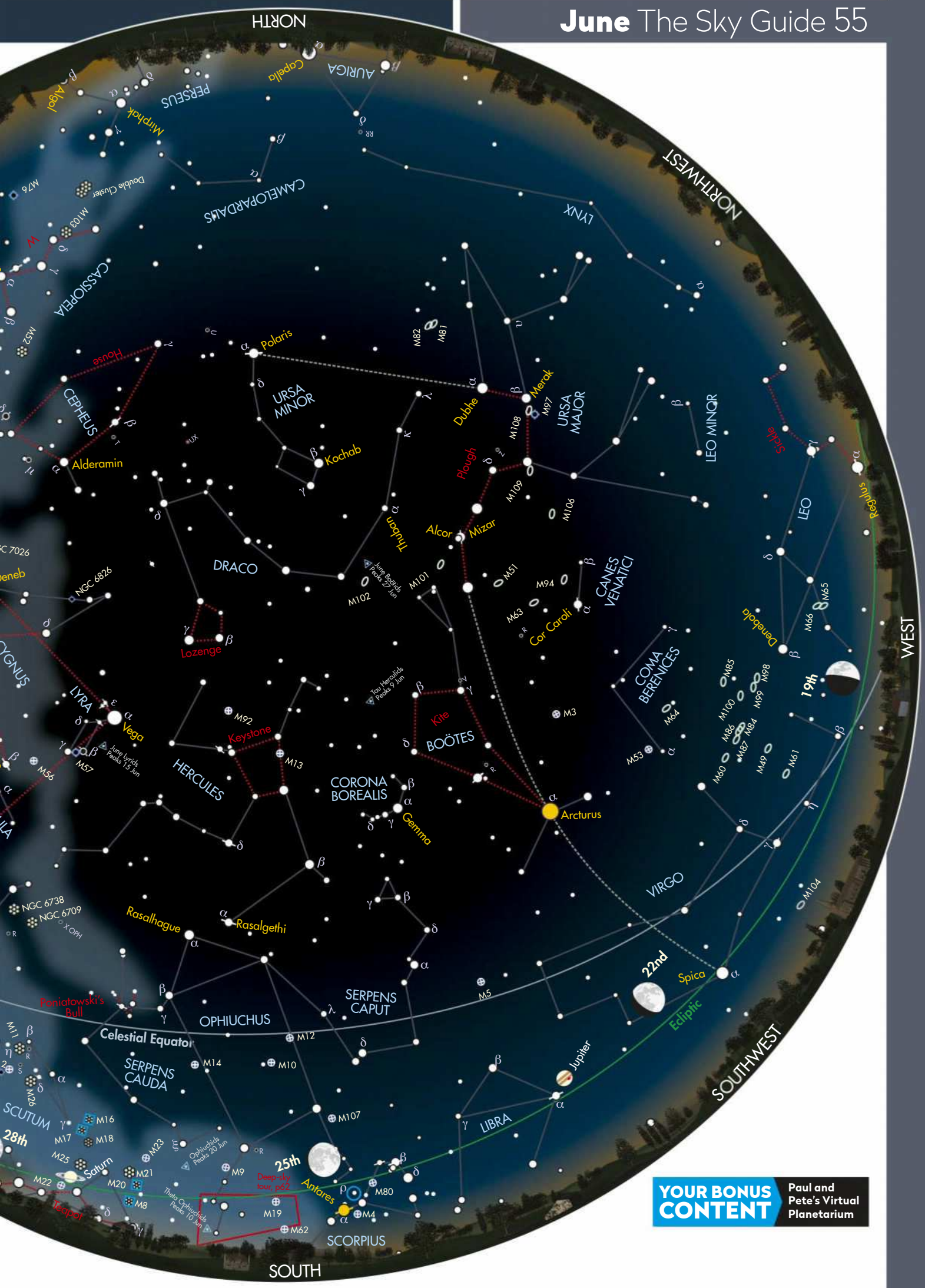


CHART: PETE LAWRENCE



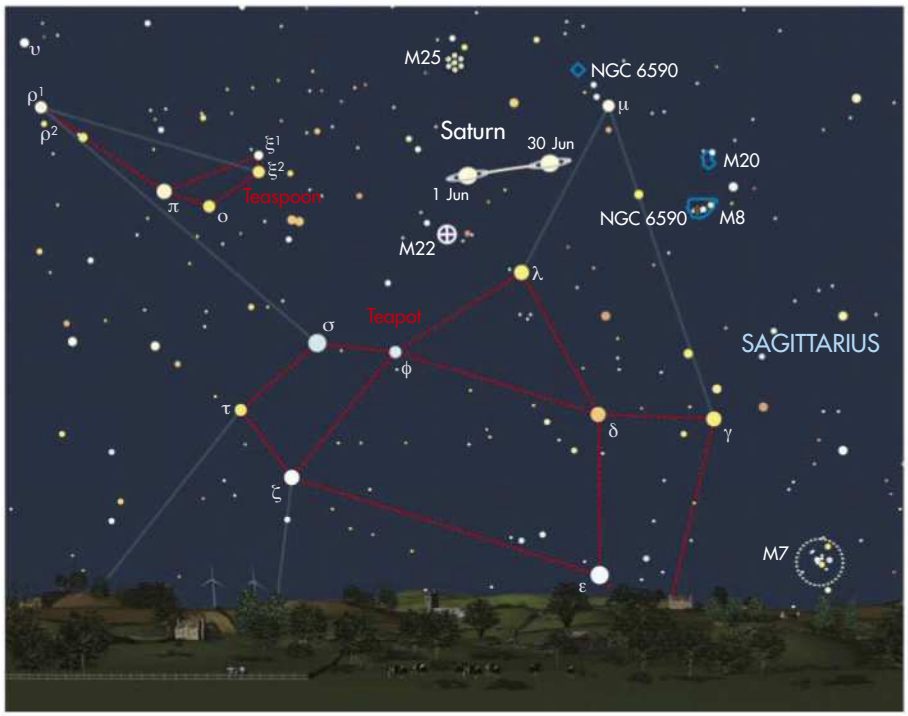
YOUR BONUS CONTENT Paul and Pete's Virtual Planetarium

THE **PLANETS**

PICK OF THE MONTH

Saturn

Best time to see: 27 June, 01:15 BST (00:15 UT)
Altitude: 14°
Location: Sagittarius
Direction: South
Features: Rings, atmospheric belts, storms and brighter moons
Equipment: 3-inch or larger scope



▲ **Saturn reaches opposition on 27 June when its rings should appear much brighter than normal**

Saturn reaches opposition this month, when it will be in the opposite part of the sky to the Sun and best presented for the year. It reaches this position on 27 June and it's worth keeping an eye on Saturn in the days before and after opposition because the planet's famous rings can brighten and fade quite noticeably over this period. They appear brightest at opposition because of what's known as the Seeliger, or opposition, effect (see page 52). At present the rings are nicely presented with Saturn's tilt being around 26°.

On 27 June, Saturn, which spends the month moving slowly westward through the northern regions of Sagittarius, will be joined by a full Moon just 2° away (the Moon also technically being at opposition). Both objects will be located to the north of the lid of the Teapot asterism in Sagittarius at this time.

Currently from the UK, Saturn never reaches a high position in the sky and this makes observing it quite a challenge. The thicker layer of atmosphere you need to look through to get a view of the planet causes its image to blur and distort. Having said that, some evenings will have more favourable conditions than others, so it's worth taking every opportunity to look at this amazing object just in case you catch a stable night.

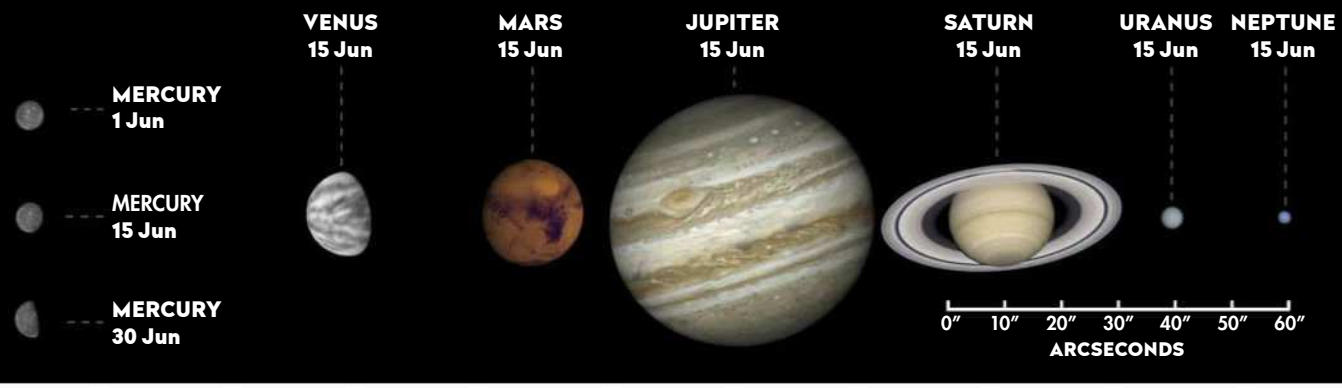
The rings are obviously the star of the show where Saturn's concerned but – as is the case with its inner neighbour, the giant planet Jupiter – Saturn's brightest moons are also fascinating to watch as they appear to dance around the planet. The largest and brightest of these is Titan and it's an interesting exercise to see whether you can spot it using binoculars. The best times to try will be on the nights of 7, 15, 21 and 30 June when the moon is furthest from the planet.

Saturn with its brightest moon Titan as they will appear on the night of 15 June through a telescope eyepiece (south is up)

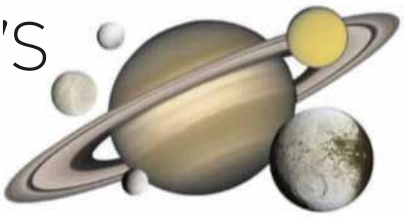
PETE LAWRENCE X 3

THE PLANETS IN JUNE

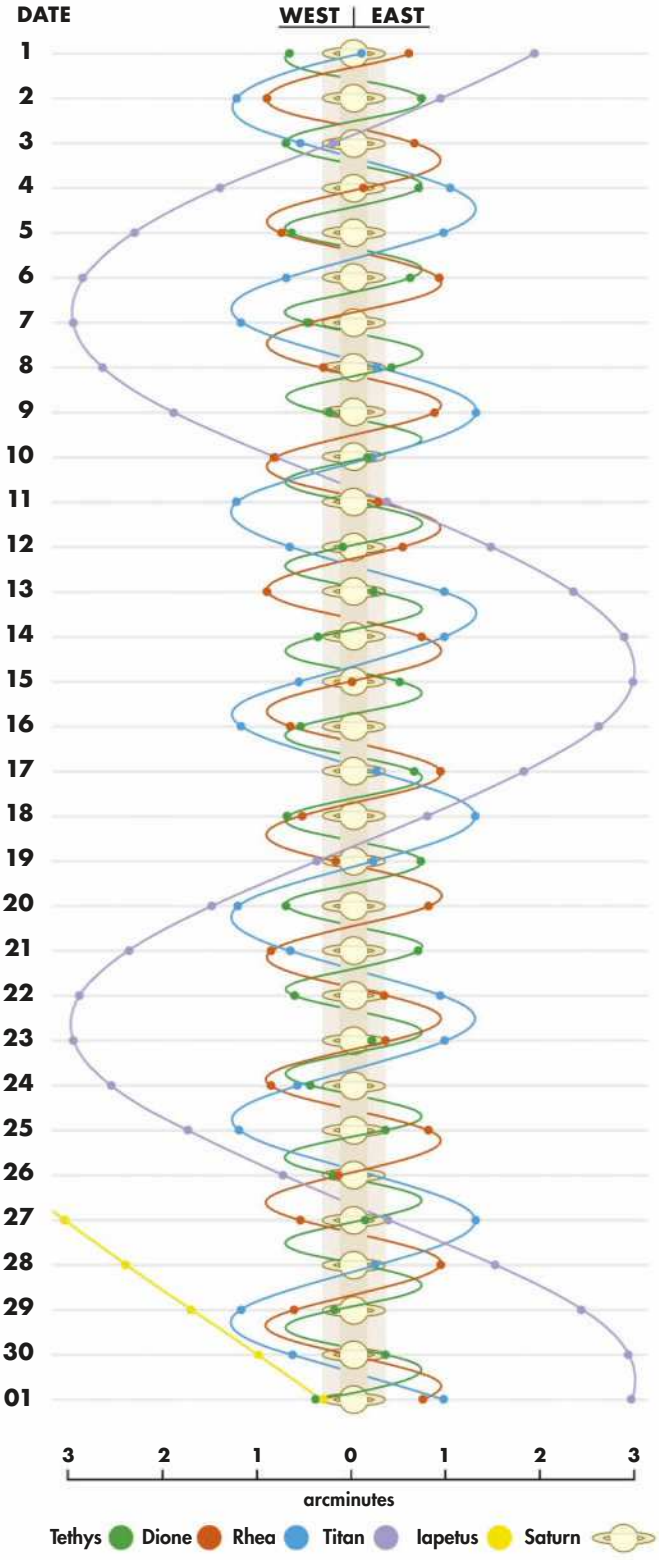
The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



SATURN'S MOONS JUNE



Using a small scope you'll be able to spot Saturn's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



Mercury

Best time to see: 30 June, 19:50 BST (18:50 UT)
Altitude: 4° (low)
Location: Cancer
Direction: Northwest

Mercury reaches superior conjunction on 6 June when it lines up with the Sun on the far side of its orbit relative to Earth. After this, it rapidly fades back into the evening twilight sky. On 12 June it can be seen as a bright, mag. –1.4 dot, close to the northwest horizon after sunset. The planet sets approximately one hour after the Sun on this date. Over subsequent evenings, Mercury's position improves as it appears to separate away from the Sun, despite the planet's brightness dimming. On 30 June, Mercury appears to shine at mag. 0 and it sets around 90 minutes after sunset.

Venus

Best time to see: 30 June, 22:15 BST (21:15 UT)
Altitude: 12°
Location: Leo
Direction: West-northwest

Venus continues to pull away from the Sun during June but its location after sunset is deteriorating. This is due to the now shallow angle the ecliptic makes with the horizon towards the west at sunset. As the planets stay close to the ecliptic this makes Venus appear low in the sky. Despite this, mag. –3.9 Venus stands out pretty well against the summer evening twilight. Look out for a lovely pairing between Venus and a 13%-lit waxing crescent Moon on the evening of 16 June. On this date Venus sets approximately 3.5 hours after the Sun. The location of Venus also means that there's an opportunity to see it close to any noctilucent cloud displays that may be visible. By 30 June, Venus will appear 15 arcseconds across and 70% lit when viewed through a telescope.

Mars

Best time to see: 30 June, 03:00 BST (02:00 UT)
Altitude: 14°
Location: Capricornus
Direction: South

Mars reaches opposition at the end of June, and is rapidly brightening and growing in size this month. Unfortunately, from the UK Mars is currently low in the sky, which reduces the amount of surface detail you'll be able to see through an eyepiece. An 82%-lit waning gibbous Moon sits close to mag. –1.3 Mars on 3 June, the brilliant planet easily standing out against the Moon's glare. As the Moon makes its way through a complete cycle and starts a second approach to the planet at the end of June, Mars will have increased in brightness to mag. –2.2, rivalling Jupiter. Its apparent diameter also continues to increase, from 15 arcseconds at the start of June to 20 arcseconds by the end of the month. On 30 June, a 93%-lit waning gibbous Moon sits 4° above Mars.

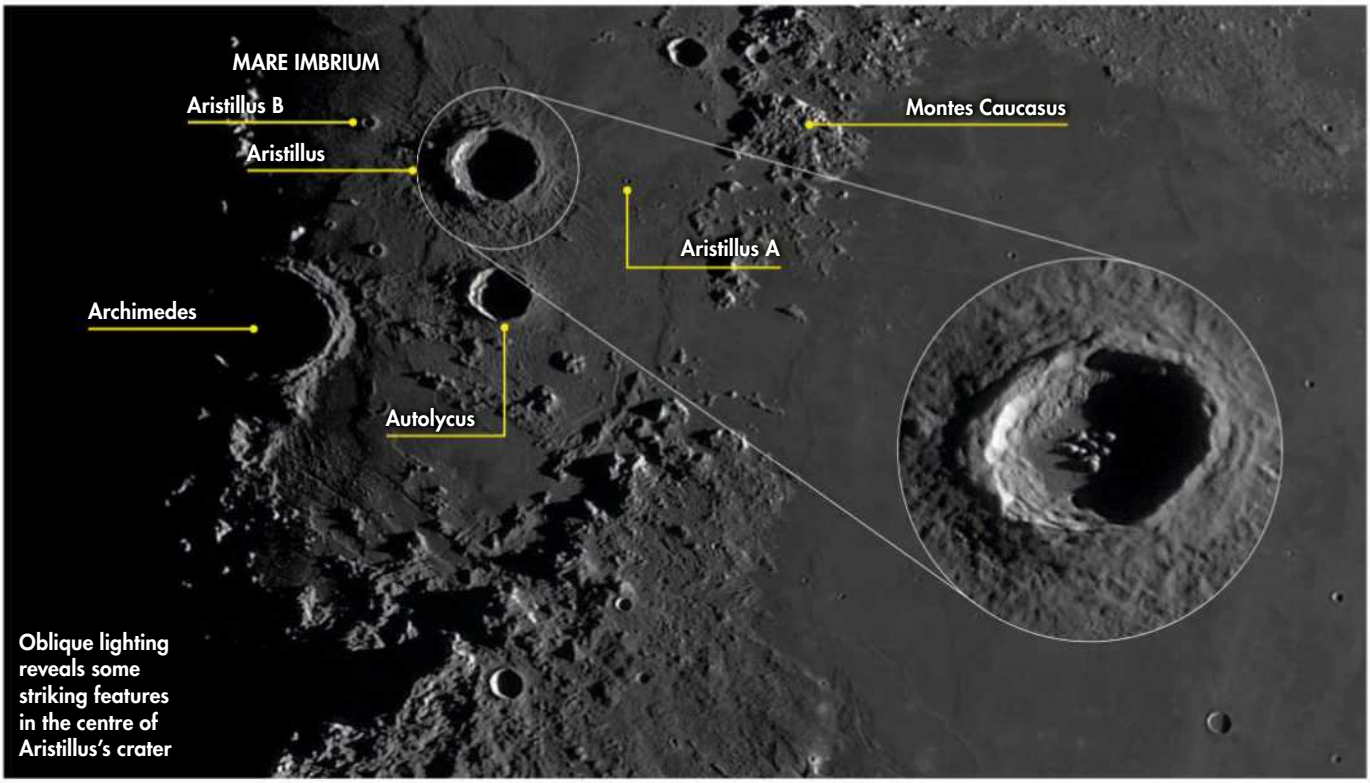
Jupiter

Best time to see: 1 June, 22:30 BST (21:30 UT)
Altitude: 21°
Location: Libra
Direction: South

Jupiter appears as a bright, mag. –2.3 evening object in Libra at the start of June. Despite a slow westward drift, it remains in Libra for the month and is fairly well placed for observation, albeit with a greatly reduced maximum altitude (around 20°) from recent years. The bright evenings around the solstice curtail plans to catch Jupiter at its highest point, the sky darkening after Jupiter has moved on. At the end of June, Jupiter remains bright at mag. –2.2, but is rapidly losing the battle against lighter evenings.

Not visible this month: Uranus, Neptune

YOUR BONUS CONTENT Planetary observing forms

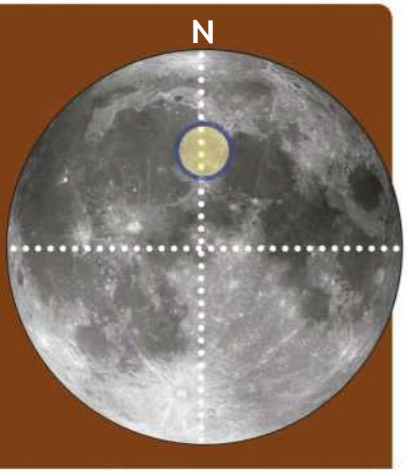


Oblique lighting reveals some striking features in the centre of Aristillus's crater

MOON**WATCH**

Aristillus

Type: Crater
Diameter: 55km
Longitude/latitude: 1.2° east, 33.9° north
Age: Up to 1.1 billion years old
Best time to see: Six days after full Moon (7-8 June) or first quarter (23-24 June)
Minimum equipment: 2-inch refractor



PETE LAWRENCE X 3

Aristillus is a prominent 55km diameter crater located in the eastern part of Mare Imbrium. It lies 100km to the north of the 40km crater **Autolycus** and 184km northeast of the distinctive and dramatic walled plane of 83km **Archimedes**.

When light falls obliquely on Aristillus near sunrise or sunset, there is a wealth of detail to be seen. A large ejecta blanket surrounds the sharp and terraced crater walls. Approximately 3.3km below, the crater's relatively flat floor is punctuated by a number of impressive peaks. These are prone to catching the early or late Sun's rays, shining against the darkness of the crater's inner shadowed floor almost like a small star cluster.

However, under more direct illumination, when the Sun is high in Aristillus's sky, detail can be seen inside the crater itself. The peaks appear highly clustered and arranged as if pointing to a common focus. The relatively sharp delineation between the terraced rim and the smooth floor is blurred to the north where it looks as if some of the inner terrace has collapsed inward.

Larger instruments may also detect an anomaly crossing the eastern part of the rim: a dark line appears to emerge where the floor meets the rim, rising over the terraces to pass over the outer rim and down into the surrounding ejecta. This feature is presumably the result of some dark material being thrown out during the point of impact.

> *"A ghost crater is clearly visible when the sun's light is low in Aristillus's sky"*

Another interesting feature lies immediately north. Easier to see under oblique lighting, there appears to be the remains of a crater flooded with lava. Although it has no official designation, the ghost crater is clearly visible when the Sun's light is low in Aristillus's sky.

Being a young formation, Aristillus has little evidence of erosion caused by subsequent bombardments; satellite craters are few and far between. You have to look 80km to the east of the centre of Aristillus using a 4-inch scope to see 5km **Aristillus A**, roughly midway between Aristillus and the impressive **Montes Caucasus** mountain range. Aristillus B is easier to see being 8km across but still lies some distance from Aristillus, located 82km to the west-northwest.

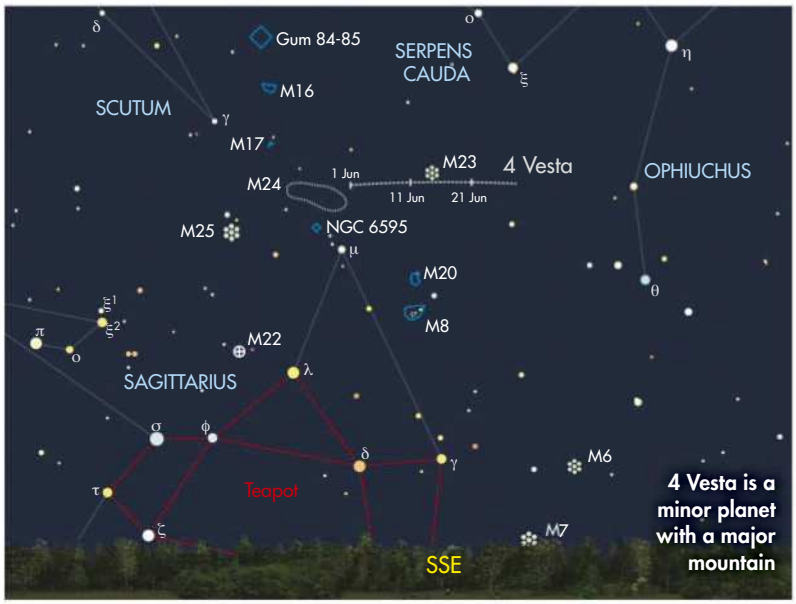
Aristillus is often paired with the equally youthful crater Autolycus to the south, partly because they lie on a north-south line from one another. Consequently, when the terminator passes over Aristillus, it also passes over Autolycus. The distinctive shadows that simultaneously form on the two craters thus present an exciting opportunity to compare and contrast the structural differences between the two features in detail.

Unlike Aristillus, 40km diameter Autolycus is less feature rich. Its rim rises above the surrounding lava and drops internally, with a notable step, to an uneven floor below. The impressive peaks that decorate the centre of Aristillus are notably absent in Autolycus. Instead there's only the weak impression of a central mound visible under oblique lighting.

COMETS AND **ASTEROIDS**

If conditions are good you may even spot minor planet 4 Vesta with the naked eye

Minor planet 4 Vesta reaches opposition on 19 June when it will be visible in Sagittarius, not far from the open cluster M23. Vesta has a high reflectivity, or albedo, of 42.3% and at the most favourable of oppositions can appear at mag. +5.1, easily visible to the naked eye. June's opposition is favourable and will see Vesta reach mag. +5.3 on 19 June, so potentially a naked-eye target if your skies are reasonably dark. Two factors will affect visibility: its relatively low altitude and the complexity of the background sky. Vesta will be located in an area of sky through which a bright part of the Milky Way flows.



At the start of June, Vesta is just west of M24, the star cloud Delle Caustiche. On 1 June it'll be at mag. +5.8, so technically visible from dark-sky locations. As it tracks west-southwest, it brightens, reaching a peak at mag. +5.3 on 18 June. It then remains at mag. +5.3 until 23 June after which it starts to dim again, down to mag. +5.5 by the end of the month.

Vesta is the second largest body in the asteroid belt with a mean diameter of 525km (the largest being the dwarf planet Ceres at 945km). Vesta takes 3.6 years to orbit the Sun at an average distance of 2.4 AU. Its axial rotation is a relatively sprightly 5.34 hours. Oblate in shape, it measures 573x557x 446km, and despite its small size relative to the main planets, it contains Rheasilvia, one of the largest craters in the Solar System. This monstrous impact crater is 505km in diameter; that's 90% of the diameter of Vesta! The crater's central peak is 22km high, just a fraction higher than the huge volcano Olympus Mons on Mars. As a result 4 Vesta, small though it may be, boasts one of the tallest mountains in the Solar System.

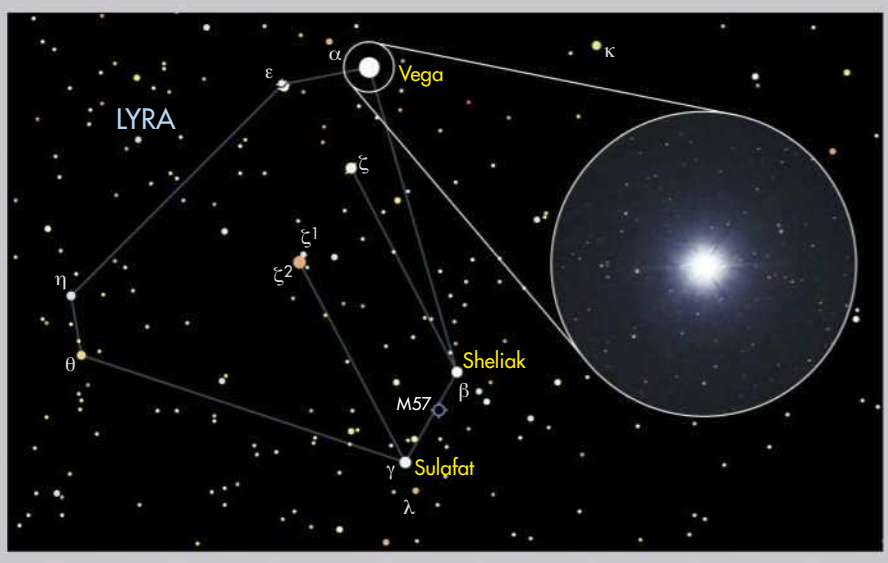
STAR OF **THE MONTH**

Vega is one of the summer night sky's brightest jewels

Vega (Alpha (α) Lyrae) is a familiar sight during the summer months, riding high in the sky, passing virtually overhead as seen from the UK. It's most obviously prominent in July and August when the length of the night starts to extend again following the northern hemisphere's summer solstice on 21 June. It's a bright star and the first one visible in the summer sky as darkness falls.

Vega is the alpha star of Lyra, the Harp, and marks the northwest vertex of the large and dominant Summer Triangle asterism. It's a relatively near neighbour of the Sun, lying just 25 lightyears away, and for a long time marked the zero point of the magnitude scale at all wavelengths. This scale is used in astronomy to denote the brightness of an object and Vega was used as the baseline value. In modern times the value is calculated numerically and Vega now has the non-zero magnitude of +0.026.

Vega is a hot, main sequence star of spectral type A0V. It is thought to be roughly halfway through its predicted main sequence lifetime of a billion years with an estimated age of around 455 million years. When it leaves the main sequence in approximately half-a-billion years it will become a red giant before finally shedding mass to end its life as a white dwarf.



▲ **Vega was once the northern pole star around 12,000BC and will be again around 13,727AD**

Its mass and diameter are roughly twice that of the Sun. From Earth we get to look down on one of Vega's poles, its spin axis tilted by around 5° to our line of sight. Vega spins with an estimated rotational velocity of 236.2 km/s. This produces an equatorial bulge and thus gives a false size to the star when measured directly.

An infrared excess was observed by the Infrared Astronomical Satellite (IRAS) in 1983, suggesting there was a ring of debris around the star, possibly the site of planetary formation. Follow-up observations by Spitzer in 2005 produced high-resolution infrared images of the dust around Vega.

STEPHEN TONKIN'S
BINOCULAR **TOUR**

This month's voyage takes in a feature once thought to be a hole in the Milky Way

☑ Tick the box when you've seen each one

1 M39

10x 50 About 2.5° from Pi² (π²) Cygni in the direction of Deneb (Alpha (α) Cygni) is the sparse but bright mag. +4.6 cluster M39, which can be visible to the naked eye in dark enough skies. 10x50 binoculars reveal a wedge-shaped group of stars. Sky conditions are crucial: in an urban sky, you may only see four or five stars, but a dark, rural sky can reveal from 15 to 20 in an area about the size of the Moon. These fainter stars change the apparent shape of the cluster from trapezoidal to triangular. ☐ **SEEN IT**

2 THE NORTH AMERICA NEBULA

10x 50 The North America Nebula (NGC 7000) is a large, bright patch of nebulosity, the centre of which is about 3.5° east southeast of Deneb. In a very clear, dark sky it is visible even to the unaided eye as a slightly brighter patch of sky. If it's not immediately visible, try instead to detect the dark nebula that forms the 'Gulf of Mexico'. This emission nebula is about 100 lightyears across and appears to us as four times the apparent diameter of the Moon. ☐ **SEEN IT**

3 THE NORTHERN COALSACK

10x 50 The Northern Coalsack (B348) is the dark patch of sky that lies very slightly east of a line from Deneb to Sadr (Gamma (γ) Cygni). It has been known since William Herschel's time, when it was thought to be one of several 'holes' or 'lanes' cutting through the Milky Way. It wasn't until EE Barnard (of Barnard's Star fame) carefully studied photographs taken with the 40-inch refractor at Yerkes Observatory in the early 20th century, that astronomers realised that it is a region where interstellar gas and dust obscures our view of the Milky Way. ☐ **SEEN IT**

4 M29

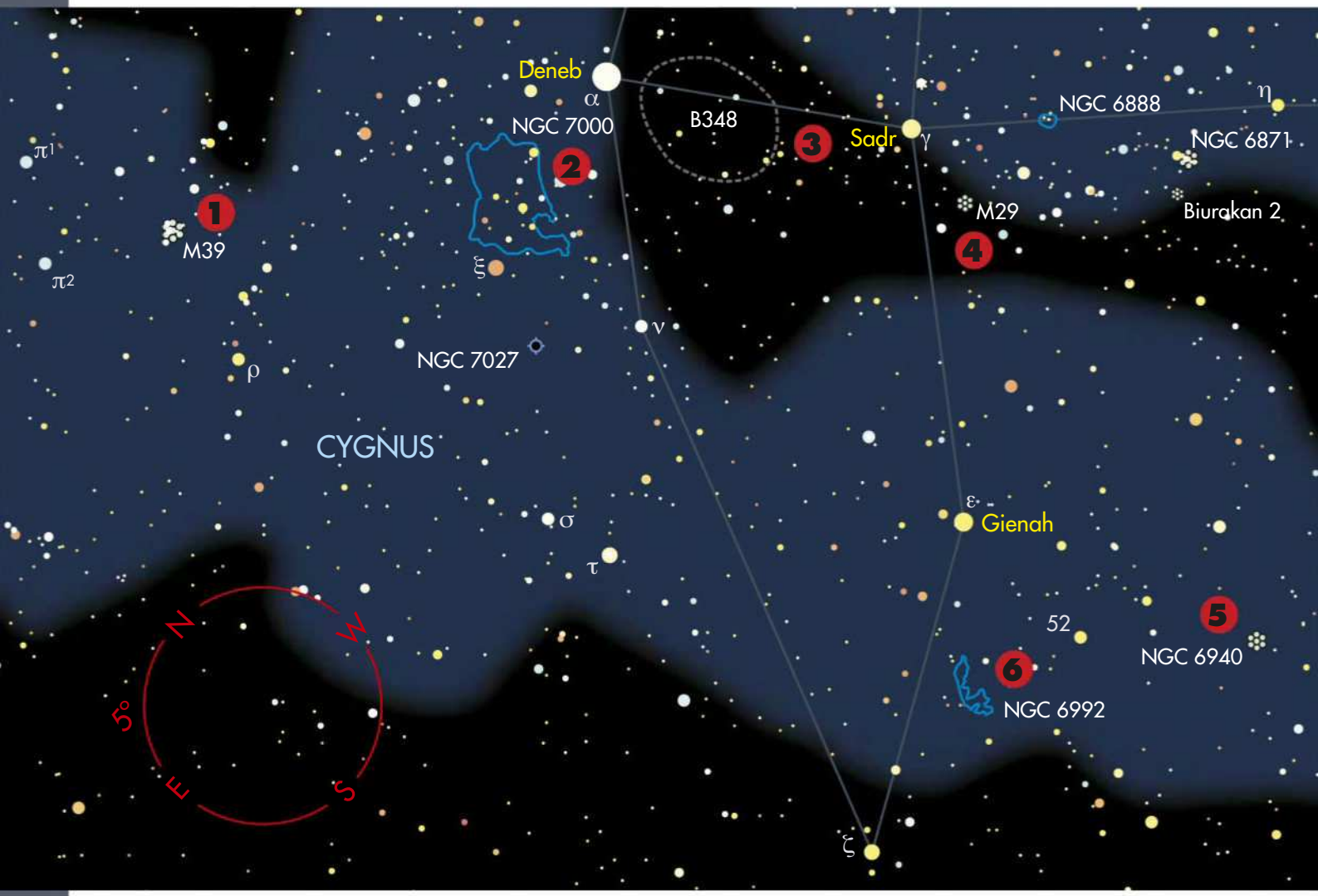
15x 70 If you put Sadr at the north of the field then the mag. +6.6 cluster M29 is near the centre, a little less than 2° south of the star. This is a fairly unremarkable cluster in smaller binoculars but, on a good night, 15x70s will resolve around a dozen stars of the 50 or so, with the brighter ones making a 'cooling tower' shape. It is about 10 million years old and its brightest stars are hot blue giants, each with a luminosity of over 150,000 Suns. ☐ **SEEN IT**

5 NGC 6940

10x 50 This is a very pretty open cluster that ought to be far better known. Start at Gienah (Epsilon (ε) Cygni) and navigate just over 3° due south to the mag. +4.2 52 Cygni. Continue the same distance southwest to find an oval glow about the size of the Moon. Study this glow and you should be able to resolve eight or more stars, depending on sky conditions. NGC 6940 is about 2,700 lightyears away and is thought to be about 800 million years old. ☐ **SEEN IT**

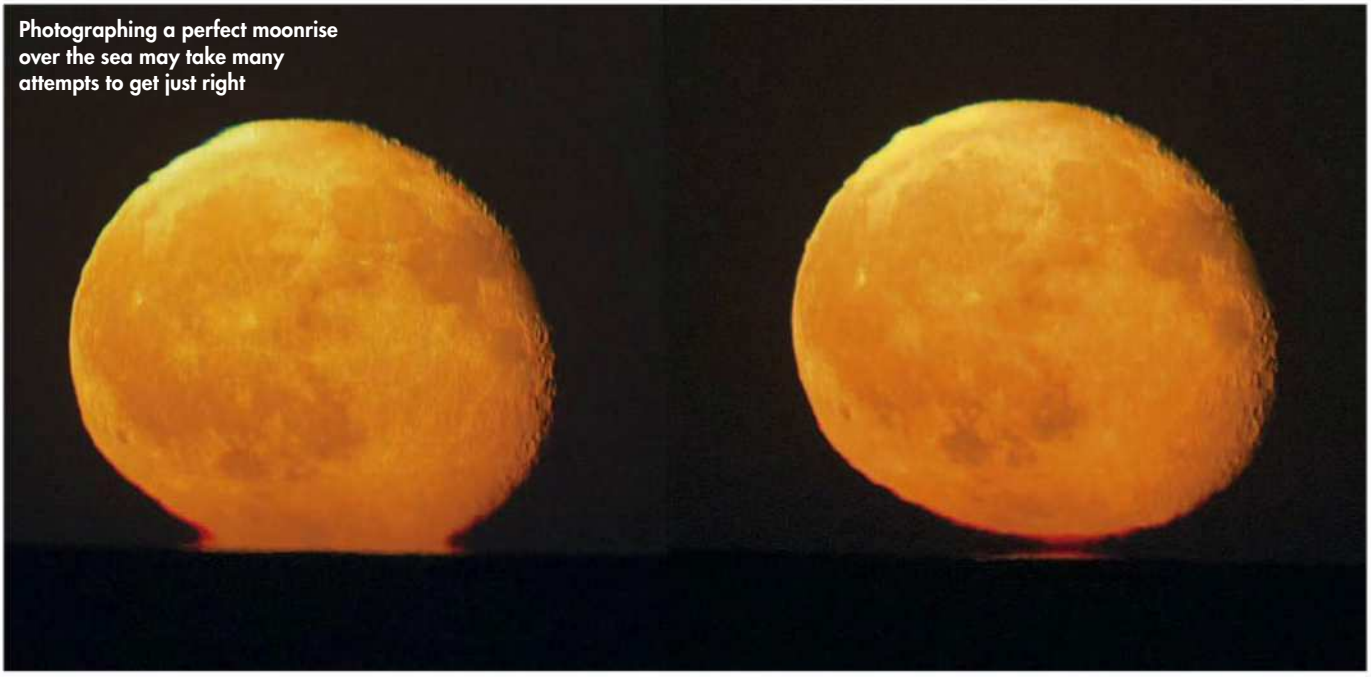
6 NGC 6992

15x 70 Our final target, the brighter part of the huge supernova remnant that forms the Veil Nebula, is a challenge for 15x70s. You need a transparent, moonless night and, preferably, to mount your binoculars. Imagine a line joining Gienah and Zeta (ζ) Cygni, then locate the middle of that line and go just under 1° (about 25% of the field of view) southwest. With averted vision and patience you should see the faintly glowing curve of the Eastern Veil, extending over about 25% of the field of view. ☐ **SEEN IT**



THE SKY GUIDE **CHALLENGE**

Capturing a perfect moonrise or moonset may be more of a challenge than you think



Photographing a perfect moonrise over the sea may take many attempts to get just right

Our amazing Moon appears quite beautiful on a clear night sky. However, its appearance close to rising or setting is often thwarted by a hazy layer of atmosphere close to the horizon. Actually, the period around rising and setting can be quite interesting to watch. The low-altitude Moon may look redder at such times. This is because the thicker layer of atmosphere its light has to pass through scatters lots of blue light. The result is a crimson-hued Moon that is sometimes mistaken in photographs for an eclipsed Moon, which also looks orangey-red.

Our challenge this month is to take the perfect moonrise or moonset photograph. By perfect we mean one in which the Moon appears bright and well defined as it rises above or sets below your local horizon. It's possible to cheat this by choosing a location where the horizon is artificially high. For example, a hill or a mountain could raise your local horizon altitude by many degrees. As the Moon reaches the point where it crosses from behind such a feature into view, it will have already cleared most of the lower atmospheric haze.

For a more adventurous result over a flat and low horizon you'll have to keep an eye on the weather. If the sky is hazy then the Moon will appear diminished. However, if there's a cloud-free high pressure zone over the UK, then the chances are that the lower sky may be haze free. Finding a day like this can be challenging and it might take many attempts to get the perfect one.

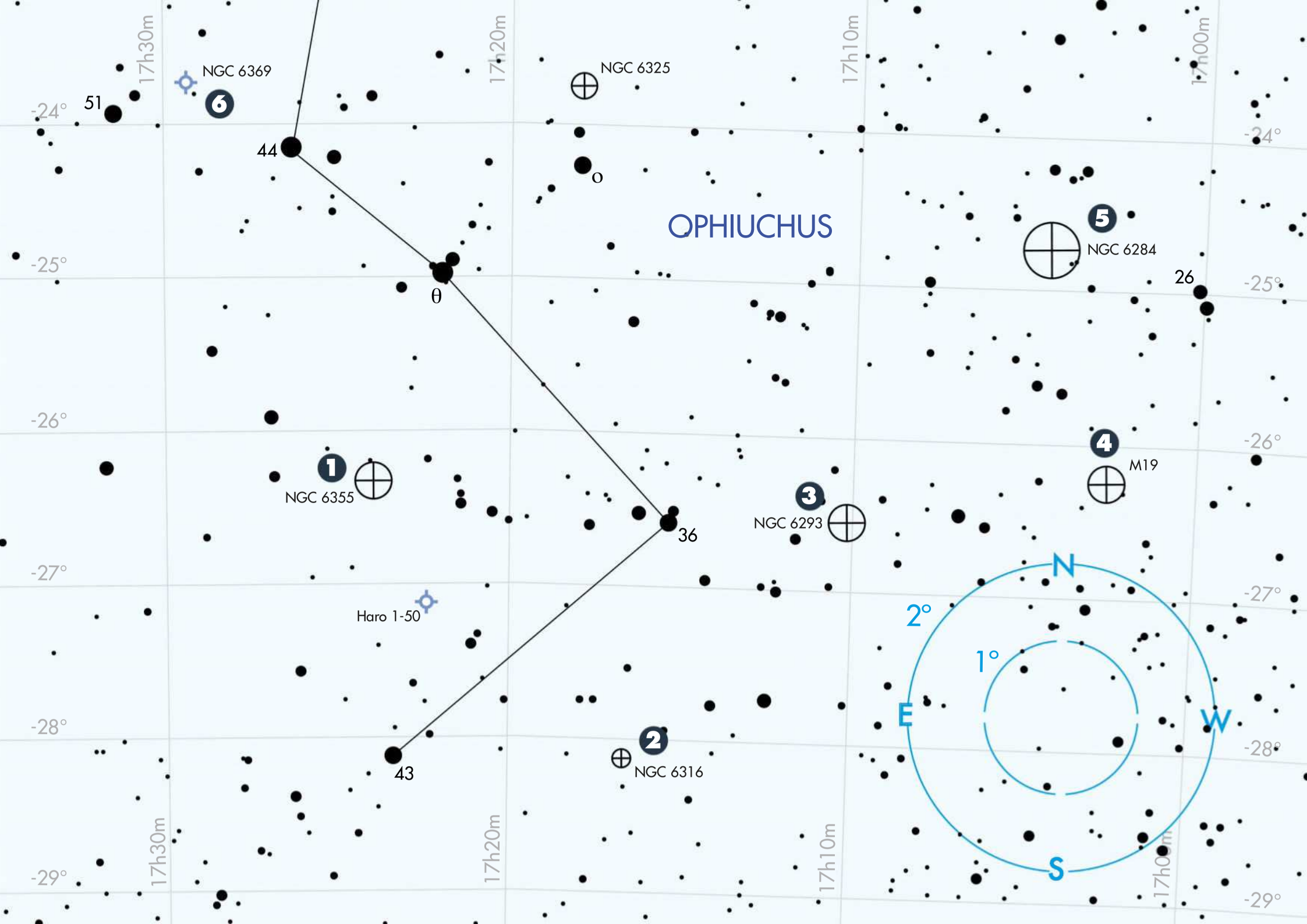
Most astronomical smartphone apps are able to give you some indication as to where and when the Moon will rise. Setting shouldn't be a problem, of course. If you're lucky enough to have access to a flat sea horizon, this will give you the ultimate rising or setting opportunity.

A DSLR attached to a telescope or a long focal-length lens is ideal for this task. If you're trying to catch a moonrise, preset the camera to a lowish ISO, say 100-200. Aim to keep the exposure fairly short and use a focal-ratio of f/8-f/11. A tripod or telescope mount is highly recommended. It's a good idea to pre-focus on a horizon object before the Moon appears but be prepared to adjust this on the Moon when it's in frame. This part can take you by surprise because the Moon may rise or set quickly. As ever, a remote shutter release will allow you to take your shots without shaking the camera.

It's surprising how an initially simple-sounding exercise can become quite an obsession. There's no doubt that capturing the perfect moonrise or moonset requires considerable luck as well as skill.

A thin, crescent Moon heavily distorted as it approaches moonset

PETE LAWRENCE X 3


OPHIUCHUS
NGC 6369
NGC 6325
NGC 6284
NGC 6355
NGC 6293
M19
NGC 6316
Haro 1-50
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DEEP-SKY TOUR

Hidden treasures and radiant gems around the eastern foot of Ophiuchus

☑ Tick the box when you've seen each one

1 NGC 6355

This month we're looking at objects around the eastern foot of Ophiuchus, the Serpent Bearer. There are some real challenges here as well as a few brighter gems. Our first target, the globular cluster NGC 6355, certainly falls into the former category. It's quite faint at mag. +9.7 and relatively small, with a total apparent diameter of just 5 arcminutes. Through a 10-inch scope it looks like a 2 arcminute glow, circular in shape and with a brighter diffuse core lacking any obvious central nucleus. NGC 6355 lies slightly less than 1.5° south-southeast of mag. +3.3 Theta (θ) Ophiuchi, and 2° to the east of mag. +4.3 36 Ophiuchi. The core starts to look elongated through a 12-inch scope, although the cluster stars never convincingly resolve. ☐ **SEEN IT**

2 NGC 6316

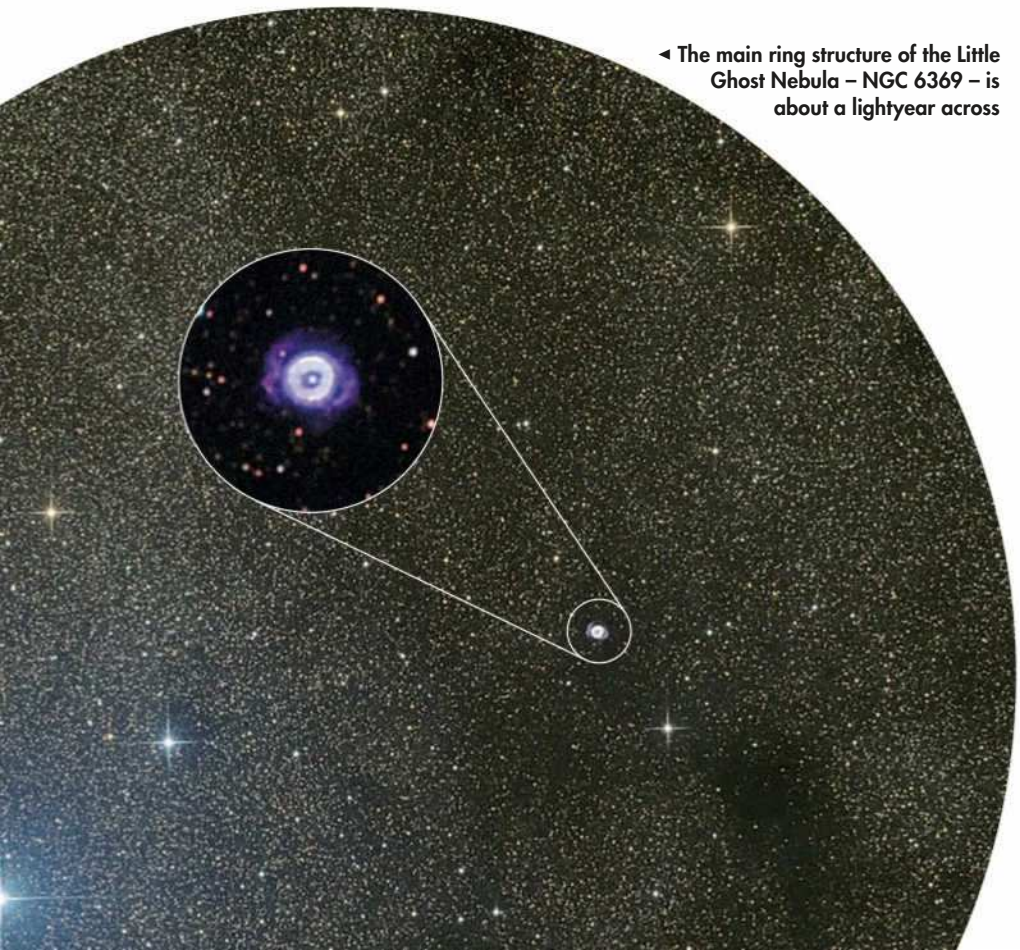
NGC 6316 is a small, 9th magnitude globular cluster located 1.5° to the west of mag. +5.3 43 Ophiuchi and a similar distance south of mag. +4.3 36 Ophiuchi. In a 6-inch scope it appears as a 2 arcminute glow at low power and isn't much more with increased magnification. In a 10-inch scope the view is quite similar with little hint of any resolution. It's only when you go to a 12-inch or larger instrument that the cluster stars start to become granular with a hint of resolution. The brightest members shine around mag. +15, making this quite a challenging object to get any real detail from. Averted vision is the best way to view it. ☐ **SEEN IT**

3 NGC 6293

Globular cluster NGC 6293 sits 1.1° west of mag. +4.3 36 Ophiuchi, the star marking the Serpent Bearer's ankle. It's a small cluster, appearing around 3 arcminutes across when viewed through a 6-inch scope. At low powers it looks like a concentrated circular patch with a noticeably brighter core, approximately half an arcsecond across. Higher powers should reveal that the outer halo is unevenly illuminated. A 250mm scope shows a mottled, granular texture at mid to high powers but a 6-inch scope is required to begin the process of resolving the 14th magnitude outliers. It's also interesting to note that the core appears to have a distinctly geometrical shape, almost triangular in appearance. ☐ **SEEN IT**

4 M19

Thankfully M19 bucks the trend of our previous targets in that it's much brighter, larger and easier to spot. It sits 3° east and fractionally north of mag. +4.3 36 Ophiuchi. At mag. +6.7 it's an easy target for smaller instruments to pick out. A 6-inch scope shows it to be elongated in a north-south orientation with a notably irregular core. This is one of the most oblate globular clusters known, although we may be getting a false impression of its shape as it is thought that the eastern edge is artificially dimmed by intervening gas and dust. A 12-inch scope resolves the entire cluster. At low powers through larger instruments, the apparent elongation gives the cluster a decidedly rectangular appearance. ☐ **SEEN IT**



◂ **The main ring structure of the Little Ghost Nebula – NGC 6369 – is about a lightyear across**

THIS DEEP-SKY TOUR HAS BEEN AUTOMATED

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

5 NGC 6284

Our penultimate target for this month is the faint globular cluster NGC 6284 which lies 1.5° to the north and slightly to the east of M19. It has a listed magnitude of just +8.9 and appears fairly small through amateur instruments, less than 2 arcminutes across. The core has a tendency to appear quite star-like through smaller instruments, with the outer regions giving it an extensive, fainter glow. As aperture increases, so the core begins to take on more of a granulated appearance. The fainter outer regions are good to view using averted vision and it's interesting to see how much larger NGC 6284 appears when you employ this viewing technique. Through a 12-inch instrument, the cluster appears more oblate than circular. ☐ **SEEN IT**

6 NGC 6369

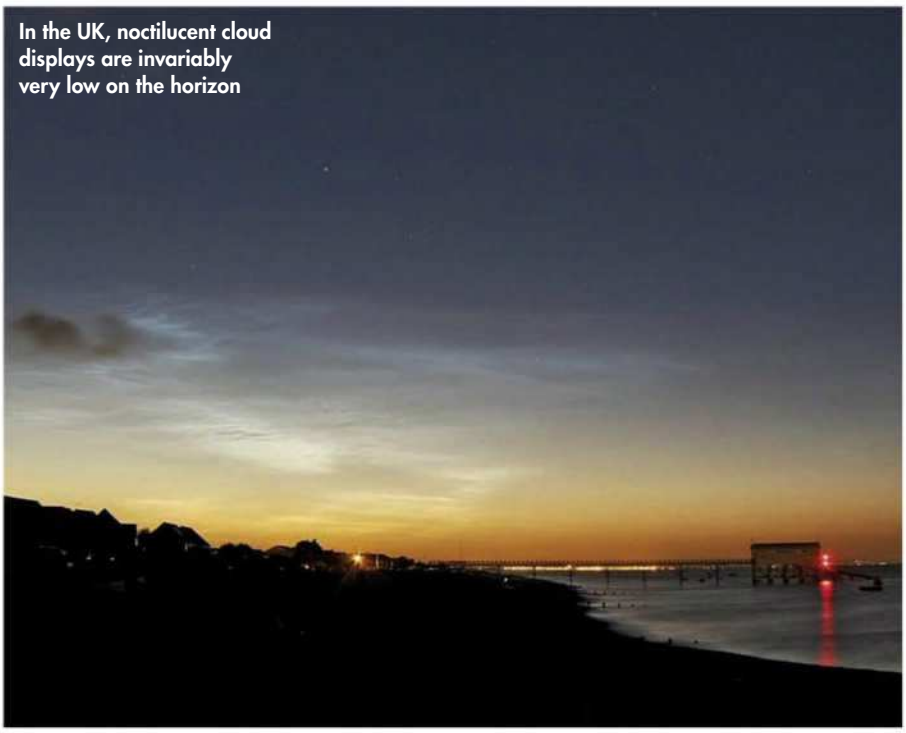
If you've had your fill of globular clusters for the month, don't worry because our final target on this tour is the planetary nebula NGC 6369, which also goes by the name of the Little Ghost Nebula. This one is a particularly faint object with a listed visual magnitude of just +11.4. Having said that, NGC 6369 can be viewed quite clearly using a 6-inch scope. Through such an instrument, the nebula appears 20 arcseconds across, or approximately half the apparent diameter of Jupiter, with a clear central hole. This annular appearance is enhanced with aperture. Such views also reveal that the annulus is not uniformly bright. A brighter arc along the northern edge is best seen at magnifications over 250x. The Little Ghost lies 47 arcminutes northeast of mag. +4.2 44 Ophiuchi. ☐ **SEEN IT**

YOUR BONUS CONTENT

Print out this chart and take an automated Go-To tour

CHART: PETE LAWRENCE, PHOTO: DANIEL VERSCHATSE/CCDGUIDE.COM, KONSTANTIN VON POSCHINGER/CCDGUIDE.COM

ASTRO**PHOTOGRAPHY**



In the UK, noctilucent cloud displays are invariably very low on the horizon

Photographing noctilucent clouds

RECOMMENDED EQUIPMENT

DSLR, tripod and a medium to wide-angle lens

THE BIG PICTURE

BE READY TO REACT TO RAPIDLY CHANGING CHANGING CONDITIONS

The elusive nature of noctilucent clouds (NLCs) turns taking a good photograph of them into something of a Holy Grail. As astrophotographic targets go, they are relatively simple to catch as long as you pay attention to what your camera is telling you. As they inhabit the brief period of sky on the edge of twilight, you have to be prepared to react to the ever-changing light levels that will try to catch you out. Constant review and adaptation is the key here, making sure that under- and over-exposure doesn't occur and that those elusive clouds remain the centre of attraction at all times. Fortunately, most modern cameras are well equipped to guide you through the process.

Noctilucent clouds, or NLCs, are high altitude clouds that may become visible from late May through to early August from mid-northern latitudes. Typically, if present, they can be seen 90-120 minutes after sunset low above the northwest horizon, or at a similar time above the northeast horizon before sunrise. They form in a narrow layer of the mesosphere at a height of about 82km, around seven times higher than the highest regular 'tropospheric' clouds. From the ground at the times stated the Sun is still below the horizon, but sunlight can still hit the higher NLC layer. There, the light reflects off ice crystals around just 40-100nm in size, creating the signature wispy, electric blue tendrils of a noctilucent display.

As the position of the Sun changes below the horizon, so the reflectance zone shifts too. If there's an extensive NLC display visible in the northwest in the evening sky, it may be large enough to survive the night, ending up as the next morning's display low in the northeast.

NLCs weren't understood for a long time as they presented two puzzles. First, what was the seeding agent around which the ice crystals formed? Second, how did the water get into the mesosphere at all? One of the first reported sightings of NLCs occurred after the Krakatoa eruption in 1883 and this hinted at fine particulates from the eruption finding their way into the mesosphere to act as seeding agents. Today we now know that fine dust from meteoroids vaporising in the atmosphere is a major contributor to the NLC seeding pool.

As for how the water gets into the mesosphere, this is currently thought to be down to a series of chemical processes possibly linked to climate change, giving beautiful NLCs a bittersweet edge.

The summer night sky is frustratingly short in duration. However, this works well for NLC spotters. Getting into the habit of an evening check, followed by a dawn check, soon becomes quite addictive and, although you will have technically been up all night, it's still possible to get some sleep!

One issue that often catches NLC hunters out is the often low altitude of displays. This isn't always the case but typically, NLCs appear in a band close to the horizon. This makes it all too easy to lose a display because it's hidden behind buildings, trees or geological features. The best advice is to find somewhere that gives you a non-obscured view to the northwest or northeast, preferably both. This sounds obvious, but it's surprising how many times an NLC display is announced on social media only to be followed by lots of posts from people saying they can't see it, even when they're in better-placed locations further north.

There is never any guarantee that a noctilucent display will happen or be extensive and bright. It's possible to spend a lot of time looking for NLCs, growing ever more despondent that nothing is happening, until you take a night off on what happens to be the brightest NLC display of the season! It really pays to remain persistent and to keep your camera close at hand throughout the NCL season. Good hunting!

▸ Read more about NLCs on page 72 and about imaging them on page 84

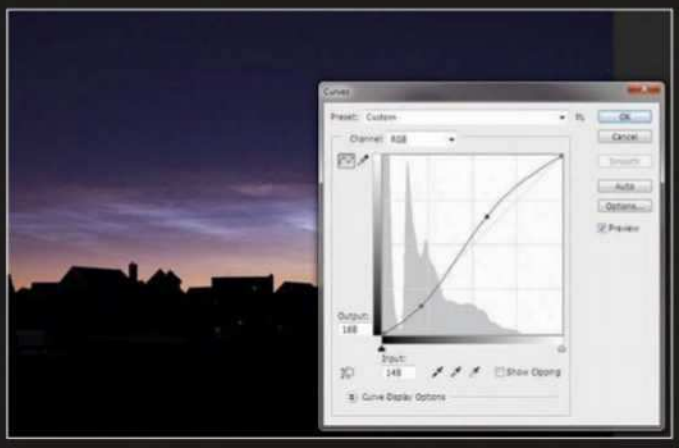
✉ Send your images to: hotshots@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

STEP BY STEP

STEP 1

Most cameras, even some smartphones, should be capable of recording a bright NLC display. Pre-focus a mid- to wide-angle lens at infinity, use a low or mid ISO and a low f/number. Tripod mount the camera and, using a shutter release cable, take a one second exposure. If the result is too dark or too light, increase or decrease ISO or exposure as required.



STEP 2

Examine the image for signs of NLCs. If there, they typically appear at low altitude as light wispy, herring-bone structures. As the sky darkens they typically increase in contrast against the darker blue of twilight. Brighter displays may appear to glow. If the results aren't clear, try loading the image into an editor and applying an 'S' curve adjustment.

STEP 3

Flicking between sequential images will produce an animation that may hint at what's going on. Alternatively, remote monitoring can be achieved by looking at NLC webcam feeds such as http://ukazy.astro.cz/nlc-monitor.php. Locating a camera east of your location may give you a heads-up as to what will be visible for you as your sky darkens.

STEP 4

Set up your camera on a tripod making sure the frame is level to the horizon. Use a mid- to wide-angle lens to frame your shot. Wide-angle is good for an overview but a longer focal length will really bring out any fine structural detail. Again, a sequence of still images animated together can bring out some incredible movement in the NLC layer.

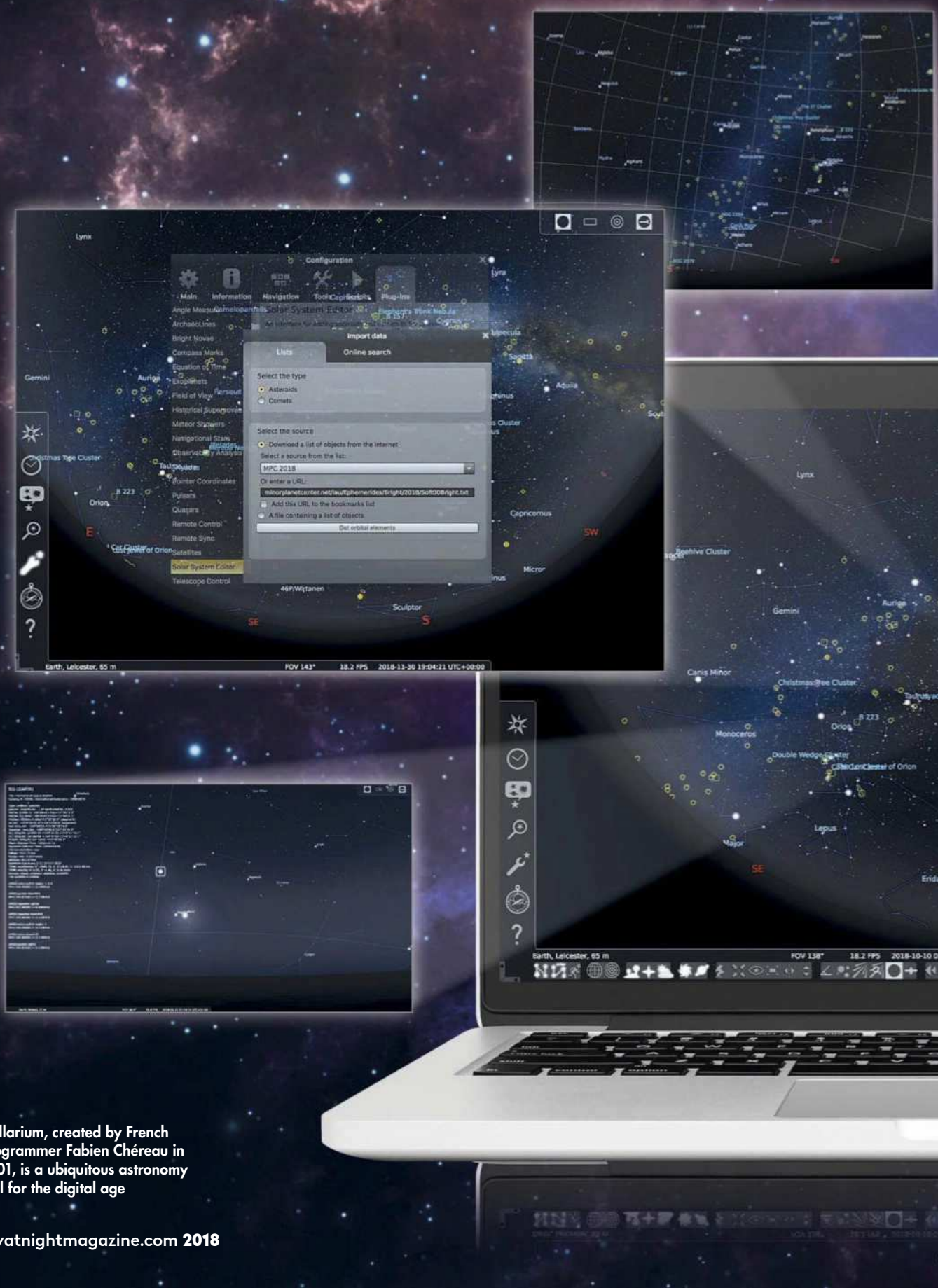
STEP 5

With more sophisticated cameras, take a shot, review the image and show its histogram. This is a graph showing the frequency of pixel values across the image. Ideally, the histogram will reach a curved peak, rising and falling between the two ends of the graph. If the peak clips at one end, the image may be over- or under-exposed.

STEP 6

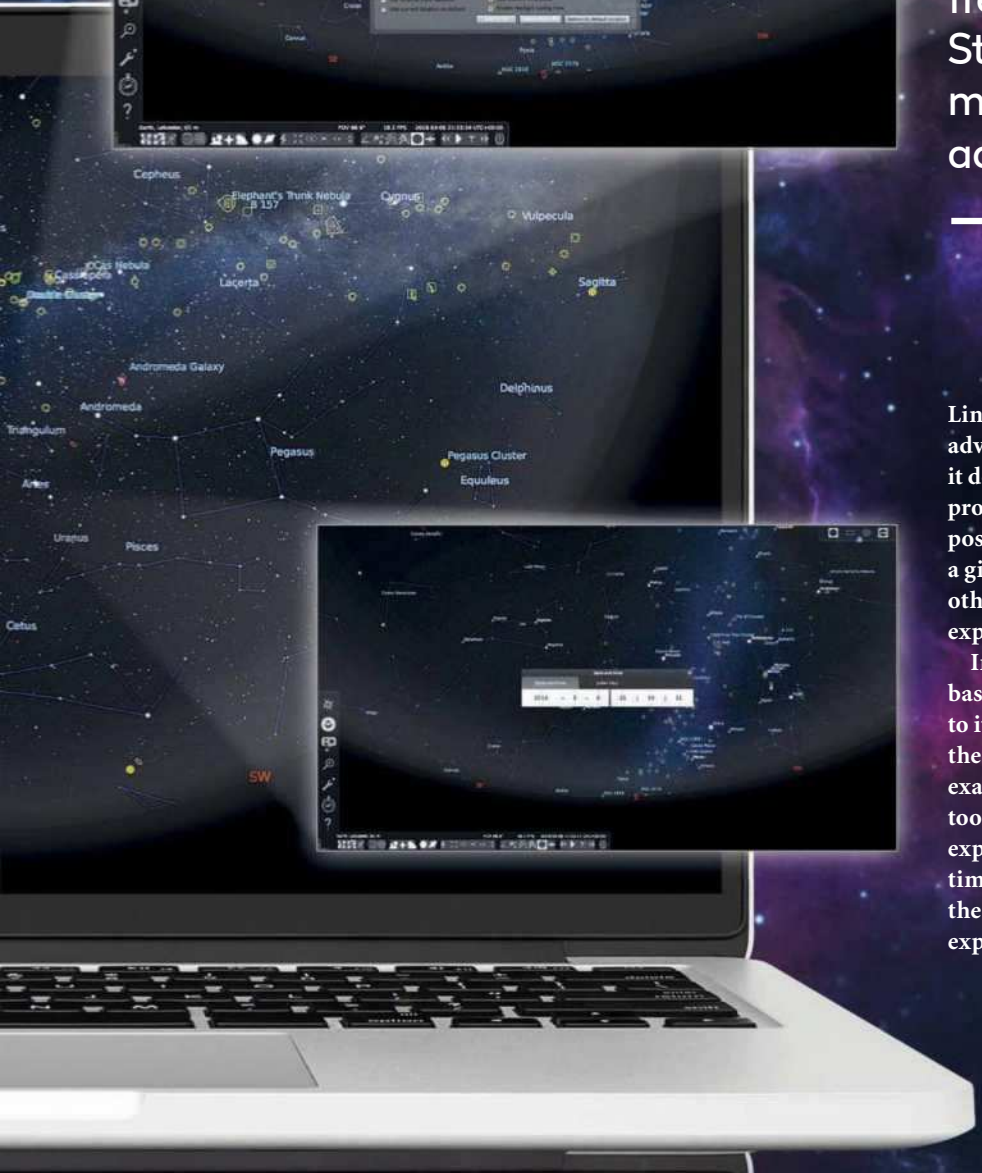
It's a good idea to place a text line at the bottom of a successful image including observational details such as date, time (UT), location, observer and equipment details. Image settings are also useful for future reference. Observation submissions can be made via national societies such as the BAA (https://www.britastro.org/aurora/nlc.htm).

STELLARIUM



Stellarium, created by French programmer Fabien Chéreau in 2001, is a ubiquitous astronomy tool for the digital age

UNCOVERED



Astronomer **Will Gater** tells you how to master the free planetarium software Stellarium and make the most of some of its more advanced features

There are few pieces of software that have made such a contribution to amateur astronomy as the free planetarium program Stellarium. Available from stellarium.org for Windows, Mac OS X and Linux systems, it is popular with beginners and advanced stargazers alike; indeed not only can it do everything you'd want from a planetarium program – that is, simulate the night sky and the positions of planets and other celestial bodies at a given date and time – but it's also packed with other features that are tremendously useful for experienced observers and astrophotographers.

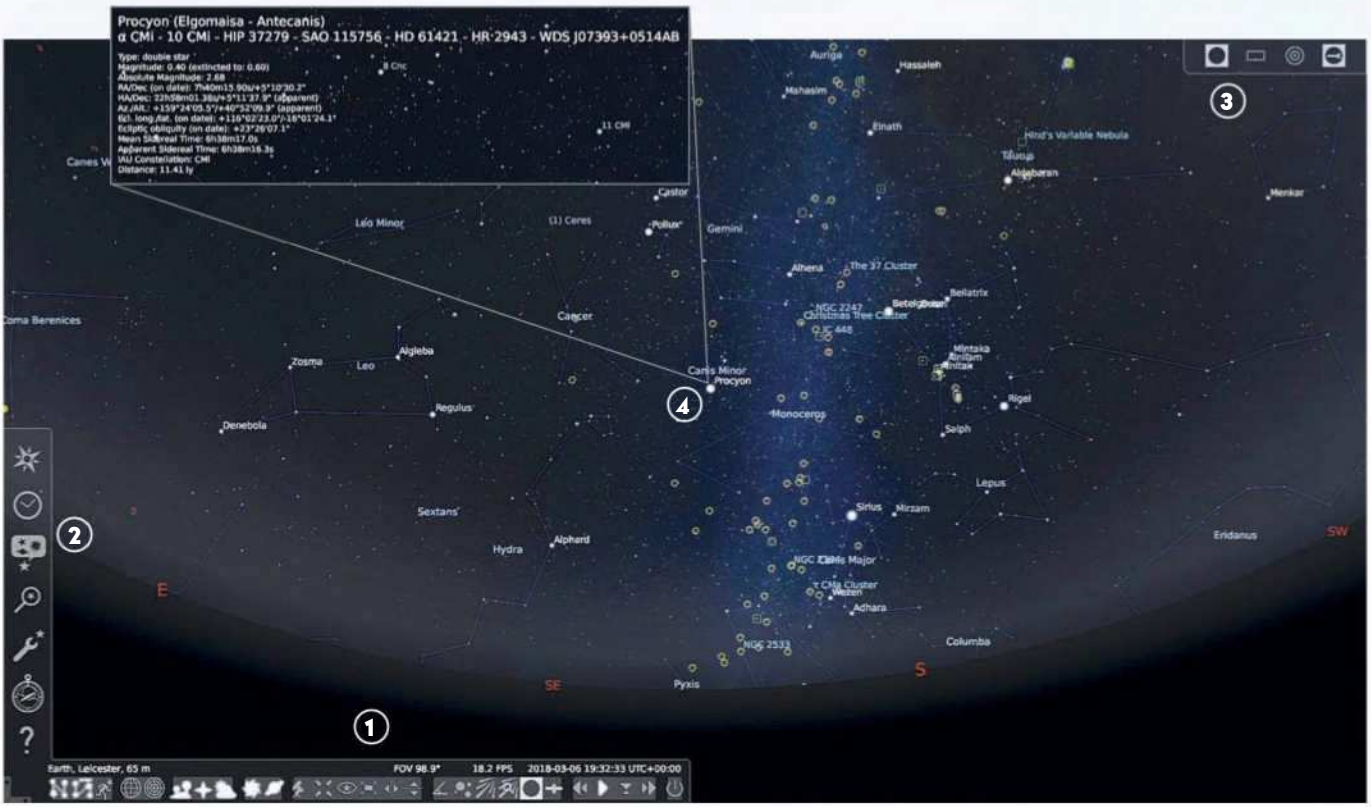
In this article we're going to first look at the basics of the program – so that if you're new to it you'll have an introduction to how to use the software – before then exploring further by examining Stellarium's plug-ins and other useful tools that even we, with decades of stargazing experience under our belt, come back to use time and time again. We suggest you fire up the program while you read this so you can experiment as we go. ▸

ABOUT THE WRITER
Will Gater is an astronomy journalist, author and presenter. Follow him on Twitter at @willgater or visit willgater.com

ISTOCK X 2, ALL SCREENSHOTS: WILL GATER @STELLARIUM

The basics of Stellarium

The symbol-based menus may seem arcane at first, but this guide will quickly get you up to speed



The main screen

1 The Stellarium main screen has two main toolbars. The bar along the bottom shows key information such as the location, the field of view (FOV) and the time. Placing your cursor over this bar will raise it to reveal buttons that can toggle various display settings such as constellation lines and star labels. This bar is also where some plug-in buttons will appear.

2 Hidden on the bottom-left edge of the screen is another toolbar with several icons. These access further configuration windows which enable you to select the location you're observing from and set the date and time, along with several display and general program configuration menus allowing you to tailor what's shown on screen, plus the Search tool and the Help window.

3 If you have the Oculars plug-in enabled (see page 70) you will see a set of icons relating to it in the top right-hand corner of the screen.

4 If you left click on a celestial object from the main screen, the object will acquire a small rotating 'target' around it (stars) or a bouncing blue 'frame' (other objects). You'll see information about the object appear at the top of the screen, including its name and other useful astronomical data, such as its magnitude and catalogue numbers. You can customise this display in the 'Information' tab of the Configuration Window, which can be accessed by pressing F2.

Setting the date and time

When Stellarium first opens it is synchronised to your computer's date and time. So if you open it during the day it'll show a simulated daytime sky. You'll need to advance the time to see the stars come out. However the program has a handy 'startup date and time' feature on the 'Navigation' tab of the Configuration Window (F2) that allows you to specify a time that Stellarium will default to – say 11pm – every time you open the program. In general use, if you want to display the sky for a specific date and time, simply click the clock icon on the left toolbar (or use F5) and input the desired values.

ALL SCREENSHOTS: WILL GATER ©STELLARIUM

Expert tips

Stellarium allows you to customise the size of stars relative to each other on-screen (press F4, Sky tag). We like to set the 'Absolute scale' to 2.20 and the 'Relative scale' to 0.50, as that gives a more photorealistic look that's useful for astrophotography planning.

Setting the 'viewing' location

Selecting the location from which you want to view the sky in Stellarium is simple. The menu can be accessed by clicking on the compass icon in the left-hand toolbar or by pressing F6 to bring up the 'Location' window. In that window, you can then choose a location by either by: clicking on a world map then selecting from a list of nearby places; typing in a town or city; or, alternatively, inputting an exact longitude and latitude. You can even select an extra-terrestrial viewing location if you want to simulate the sky from other bodies within the Solar System.

Exploring Stellarium's sky

To explore the sky in Stellarium you can drag it round with your mouse or use the arrow keys on a keyboard. To zoom in and out use 'ctrl' (or 'cmd' on a Mac) plus the up and down arrows, or you can use a roller wheel on a mouse. To zoom in on a specific target first left click on it, then press the spacebar to centre it before using the zoom keys (as above).

Expert tips

Ordinarily the two toolbars are hidden unless you move your cursor near them. They can be 'locked' in place by clicking the tiny triangles on the 'L'-shaped tab in the bottom-left of the Stellarium window.

Using the search function

Stellarium's search menu can be accessed by pressing F3. Pressing the 'return' key on a successful search will immediately centre that object on the screen.

How to tweak what Stellarium shows

Pressing F4 brings up a 'Sky and viewing options' window where you can customise Stellarium's view. From the 'Sky' tab you can change the size of the stars, adjust the number of labels and limit star magnitudes, which is useful for decluttering the chart. You can simulate light pollution to work out what's visible from an urban observing site. From the 'DSO' tab you can choose which catalogues of deep-sky objects are flagged, while the 'Markings' tab allows you to switch between various celestial markers, lines and coordinate grids. The 'Landscape' and 'Starlore' tabs give the option to change the foreground scenery and alter which culture's star names and constellation patterns are used.

Other stargazing software choices

There are many other sky charts programs available if Stellarium doesn't quite fit your virtual stargazing requirements:

Sky Safari: skysafariastronomy.com

Starry Night: www.starrynighteducation.com/index.html

Cartes du Ciel Skychart: www.ap-i.net/skychart/en/start

Google Sky: www.google.com/sky/

Redshift: www.redshift-live.com/ext/en/

ESA Sky: sky.esa.int/

Sky Map: www.sky-map.org ▸

Advanced features

Here we delve deeper into Stellarium to look at some of the useful plug-ins for imagers and observers

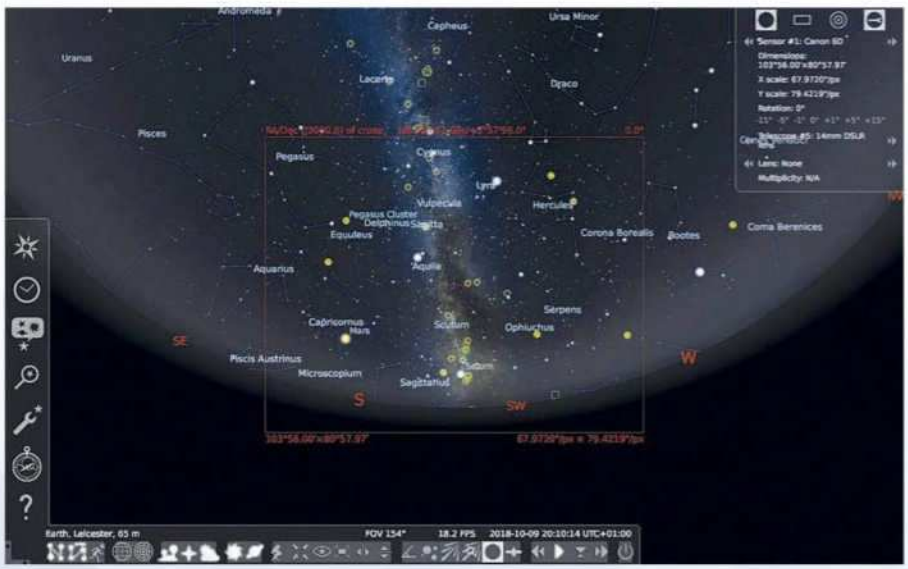
Simulating eyepiece and camera fields of view

Stellarium comes with an extremely useful feature – the 'Oculars' plug-in – that allows you to simulate the field of view of a given eyepiece and telescope combination as well as overlay the field of view of a camera and optics setup onto the sky. Of all the plug-ins in the program this is the one we use the most and its ease of use makes it a superb tool for planning astrophotos.

The plug-in can be activated by accessing the 'Configuration' window using the F2 button, then clicking on the 'Plug-ins' tab. In the window that appears, scroll down the menu on the left to 'Oculars' then click on the 'Load at startup' button at the bottom. When you reopen Stellarium, you'll see a new toolbar has appeared in the top right of the screen.

The rightmost of these (a spanner symbol) brings up the plug-in's Configuration Window where you can list what telescopes, eyepieces and cameras you own, with a mask covering the rest of the sky. The second button activates a camera field of view tool that, when clicked on, places a red box onto the simulated sky representing the boundary of the field of view of the specified equipment setup. The third icon switches on a circular 'target' pattern that's used in Telrad finders.

Swapping between various eyepiece and scope pairings – or between different combinations of camera and telescope (or indeed camera lens) – while using the program is easy: simply click the double arrows next to each piece of equipment listed in the box under the toolbar, which appears when either the eyepiece field of view or camera field of view tools are in use. The camera field of view can even be rotated by different increments when it's shown, so you can experiment with the ideal framing and composition of a potential astroimage.



ALL SCREENSHOTS: WILL GATER ©STELLARIUM

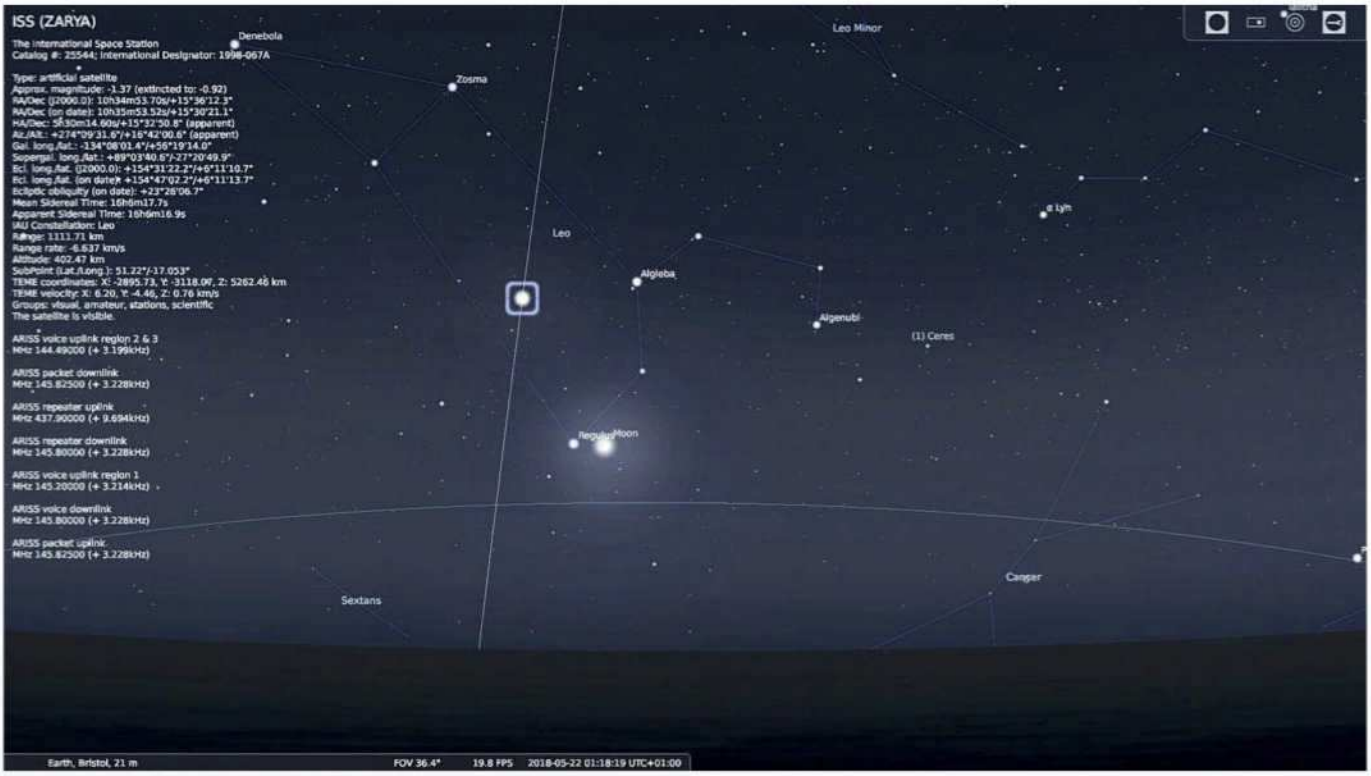
Expert tips

Clicking on the 'eye' symbol on the bottom toolbar activates a night-vision mode that tints the whole Stellarium window red, to help preserve your dark adaptation if you're using the program while observing.

Using and updating the 'Solar System Editor'

Stellarium doesn't just simulate the positions of stars, deep-sky objects, the planets and the Moon in the sky. It also shows where numerous asteroids and comets are located at any given moment. New comets and asteroids are discovered frequently and you can keep the program's databases of these objects up-to-date using the 'Solar System Editor' plug-in located in the Plug-Ins menu in the Configuration Window (accessed with F2).

Clicking the 'configure' button on the Solar System Editor page brings up a new window with a 'Solar System' tab. On this tab there is a button to 'Import orbital elements in MPC format'. Selecting this will bring up a window that enables you to download orbit data for both asteroids and comets from various lists maintained by the Minor Planet Center; you simply select which list you want to import from the drop-down menu, click 'Get orbital elements' and then select which bodies you want Stellarium to plot before clicking 'Add objects'. You can then search for these objects using the search function (F3).



Showing satellites

Among the many excellent advanced features contained within Stellarium, the 'Satellites' plug-in is likely to be the one that will be of most interest to watchers of humanity's orbital outposts. Once enabled via the 'Plug-ins' menu, it plots the positions and movements of a huge number of satellites. This is not just interesting to look at, it also creates a superb planning tool for astrophotographers who enjoy taking pictures of things like the International Space Station, geostationary satellites and iridium flares – especially when it's used with the camera field-of-view function in the 'Oculars' plug-in. For example, if the ISS is going to make a pass over the location that Stellarium is simulating the sky for, the program will show it as a bright point of light moving against the stars, just as you would see it in real life. Stellarium will even simulate the Station going into – or emerging out of – Earth's shadow if that occurs on the pass. To make the path of the ISS even clearer we advise checking the 'Orbit Lines' box on the plug-in's configuration page. In addition to this the plug-in even simulates – in a realistic manner – the 'flaring' behaviour of iridium flares, with the satellite momentarily brightening dramatically before fading.

Expert tips

To find whether a meteor came from a shower, use the 'Angle Measure' plug-in to draw its path, then use 'Showers' to see which radiant its path matches.

ABOUT THE WRITER
Adrien Mauduit is an aurora-chaser, astrophotographer and science educator. www. adphotography-online.com

Capturing the CLOUDS

A view of noctilucent clouds through the Plexiglas window of the team's plane travelling at 20,000 feet

The team's Mooney M20K aircraft on a runway in Alberta, against a backdrop of noctilucent clouds

NLC photography specialist **Adrien Mauduit** joins a team of scientists flying to the upper atmosphere to catch an up-close glimpse of a noctilucent display

YOUR BONUS CONTENT Find out more about noctilucent clouds and watch some of the NLC time-lapse videos captured during the mission.

We look out of the Plexiglas window as our aircraft climbs steadily above a thin lower cloud layer. To our left the rising, waxing gibbous Moon barely shines through distant thunderstorms, given away only by flashes of lightning. In front of us a tiny speck of city light glows in the dark, remote, Canadian sub-boreal forest, reminding me that we are climbing towards 20,000 feet above the ground. As the air in the cockpit becomes dangerously thin, Jason signals to Aaron and myself to put on our oxygen masks. I feel the adrenaline rush through my awkwardly moving arms as I struggle to fasten and adjust the O_2 system in the darkness of the cockpit. While my fellow passengers make sure I'm securely geared, I peek out again at the panoramic view.

"Look! They're there!" I scream into the microphone, my heart pumping out of my chest. "Noctilucent clouds to the north!"

Behind me, Aaron quickly manages to adjust his equipment to record the elusive silver-glowing bands from the confined space of the cabin, but he can barely hide his excitement. Aaron's previous sortie to search for noctilucent clouds (NLCs) left ▸

Adrien Mauduit on his first airborne mission to photograph NLCs

ALL PICTURES: ADRIEN MAUDUIT

▲ The Red Sprite team. From left to right: Adrien Mauduit (photographer); Shawna Pandya (MD); Armin Kleinboehl (NASA researcher); Casey Stedman (pilot); Jason Reimuller (pilot, executive director of PoSSUM); Anima Patil-Sabale (pilot); Chris Lundeen (technician)

This is how Adrien's equipment was mounted in the plane

ADRIEN MAUDUIT X 5, ILLUSTRATION BY STEVE MARSH

▸ him empty-handed; this is how unpredictable and exciting working conditions get when conducting airborne research on such a fleeting astronomical phenomenon as this one.

Noctilucent clouds – literally 'night-shining clouds' in Latin – are found in Earth's upper mesosphere at about 82km above sea level. This makes them the highest clouds on Earth, forming about 10 times higher than those in our lower atmosphere. They're also some of the rarest, as they only occur under certain conditions. In the northern hemisphere they form in the summer months, roughly from the end of May until the start of August, when the air in the atmosphere is at its warmest and expands upwards, allowing the mesosphere to cool down. This layer of sky is generally extremely dry but moisture can form as the result of a number of different factors. As water molecules accrete onto dust particles in the mesosphere, the cold temperatures (–120°C and below) trigger the nucleation process, creating tiny ice crystals. As a rule they cannot be detected unless sunlight hits them from a certain angle, between six and 18 degrees under the horizon during twilight or dawn. The Sun reflects its rays onto the ice particles, making them shine in the dark. Observers located at latitudes from about 45 to 60 degrees north have the best chance of spotting this unique phenomenon.

Playing PoSSUM

That is why a group of astronaut candidates and graduates from a non-profit research organisation called Project PoSSUM (Polar Suborbital Science in the Upper Mesosphere) chose that precise location (58.5°N) and time of year (24 June – 9 July 2017) to study NLCs as they had never been studied before. I was invited to join them in the hope I could put my NLC-imaging skills to practice. I had already been capturing NLCs for four years in Denmark but this expedition would allow me a closer look.

Arriving at the isolated 'PoSSUM den' in High Level, Alberta, I met Dr Jason Reimuller, PoSSUM executive director and command pilot, along with the first of two weekly teams of four volunteering scientists. The first week's team was christened 'Red Sprite' and the second week's 'Blue Jet'. A smaller team that stayed for a third week was called 'Pixie'. The team names were terms for other atmospheric phenomena that mission was studying at the same time as NLCs. My future flight companion Aaron Persad, a trainee astronaut with the Canadian Space Agency, would join us in the sceond week.

I barely had time to unload the car after my eight-hour trip through the Canadian wilderness,

▲ **Top: A monochromatic image of NLCs taken from the ground, used to create tomography (3D modelling). Above left and right: The ground crew at work imaging the NLCs**

when we had to be briefed for our first research sortie. Jason divided up team 'Red Sprite' to operate two ground stations located 200km apart, plus an airborne plane station, all of which would be working simultaneously to capture monochromatic images of NLCs from which to build tomographic (3D) models of the phenomenon.

"Safety and good crew communication are not to be taken for granted," Jason reminded us cautiously. "They must come first, especially when working in such a remote area and in an unpressurised-cabin aircraft. All the members of the team agreed that weather conditions were excellent and gave a 'Go' decision for all three stations.

I took advantage of a five-minute window to chat with PoSSUM citizen astronaut candidate Anima Patil-Sabale. "Besides the amazing experience, this campaign is the opportunity for astronaut candidates to put theory into practice and really do hands-on citizen science" she told me.

Cloud coverage

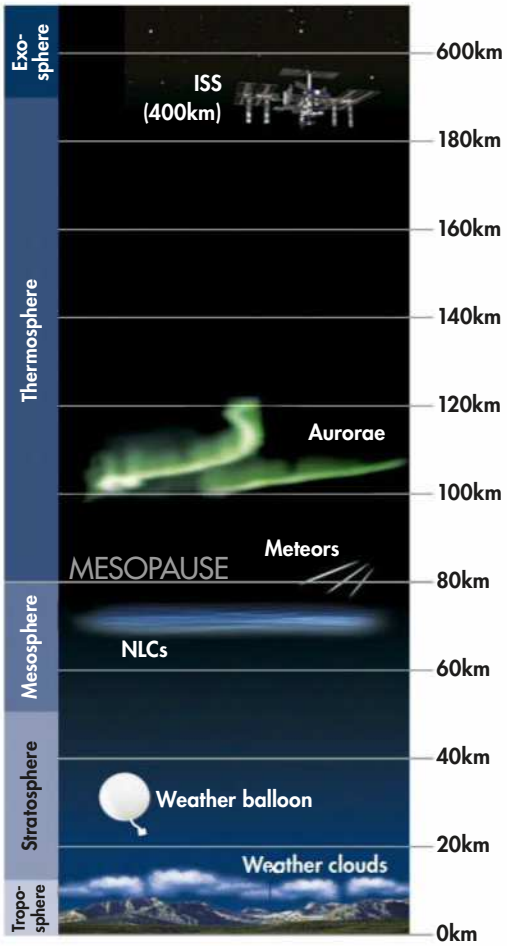
Each ground station housed a specially designed, NASA-funded, 16 megapixel camera with a Canon 135mm f/2 lens capable of taking a series of monochromatic pictures pointed at an elevation angle of 15 degrees above the horizon. The aircraft camera was mounted on a sturdy rig and pointed through the aeroplane's window.

All the cameras were connected to specially designed computers and were working in conjunction with customised, interactive software from which the shutter speeds were manually adjusted, depending on the brightness of the scene. The apertures were set wide open to take advantage of all available light from the low-light scenes, ▸

Understanding the UPPER ATMOSPHERE

Too high to reach by balloon or aircraft, yet too low to reach by satellite, the mesosphere remains a frontier of our atmosphere only visited by a few passing astronauts. Our knowledge to date has been mostly limited to remote sensing methods and limited sounding rocket observations. Yet this poorly charted layer is possibly the most sensitive part of our entire environment. It is a region where energy convected up from Earth interacts with energy transferred and deposited by the Sun, creating extremely intricate dynamics further complicated by the presence of ionised particles from our lower ionosphere.

Noctilucent clouds are the major feature that we can observe at those altitudes and very small changes in our lower atmosphere have been observed to cause widespread changes in NLCs. Notably, the increased presence of noctilucent clouds is largely believed to be attributable to the increase of carbon dioxide and methane in the atmosphere; the major man-made drivers of global climate change. But a better understanding of this region may allow for more operable spacecraft that will transit through this region and also enable a better understanding of low-density atmospheres elsewhere, such as Mars.



▲ **A handy mnemonic for remembering the layers in order: Tropical Skies Must Thunder Eventually**

Some of the project's instrumentation had to be specially adapted for high altitude use

Planning for PoSSUM

How this unique cloud-seeking mission came to be

Since 2011, NASA has been interested in using commercial sub-orbital spacecraft designed for tourism, such as Virgin Galactic's Spaceship Two, to enable science and develop new technologies. PoSSUM grew from a sub-orbital flight opportunity granted by NASA in March 2012 to fly a suite of instruments through a noctilucent cloud layer and image in 3D the fine structures of these clouds. The experiment was an extension of Dr Jason Reimuller's work imaging the clouds from aircraft, and it was deduced that stabilised tomographic imagery from a suborbital spacecraft would greatly improve the existing models of our upper atmosphere, to better address questions relating to how energy and momentum are transported through it. The mission required precise planning, and instrumentation had to be developed that could be controlled by an operator in a pressurised spacesuit.

Since most people know little about our upper atmosphere, it was a unique opportunity to communicate science to broad audiences. In 2014, PoSSUM partnered with Embry-Riddle Aeronautical University to train interested individuals to conduct this mission. The graduates stay engaged with upper-atmospheric research, such as the High Level Airborne Campaign, bioastronautics and spacesuit research, and science education missions, while they wait for their opportunity to fly to space as part of a PoSSUM suborbital research campaign. The programme emphasises international participation and to date has attracted members from 24 different countries across all six continents.

▸ while the ISO and focus remained untouched in order to ensure a consistency in the data collection. The research aircraft, a Mooney M20K, was to fly on a longitudinal line and shoot pictures towards due north, corrected at five waypoints along the flight trajectory. Each ground station camera had to correct its azimuth angle to capture the same area of the sky as that of the aircraft. Although using the aircraft as a mobile station introduced its own challenges, such as jittering and blur from the Plexiglas window, it allowed us to get much clearer and better contrasting images as it flew at

▾ Below from left: the team preps for an NLC-capturing flight

ALL PICTURES: ADRIEN MAUDUIT

A view of noctilucent clouds from the PoSSUM research station in Alberta

▲ The team's Mooney M20K aircraft soars into the twilight Canadian skies where NLCs are already forming

23,000 feet above 60 per cent of the atmosphere, significantly increasing the signal-to-noise ratio.

"I saw my first noctilucent clouds from 21,000 feet, and it was such a magical moment," PoSSUM Academy graduate Alyssa Carlson explained as she was coming out of the aircraft after her first airborne sortie. "We also got to see jaw-dropping aurorae right on top of the display."

A new perspective on NLCs

I was deployed at the High Level ground station for the two-week duration of the project to help with ground imagery, using three of my own low-light performing commercial cameras (a Sony α7S, a Sony α7R II and a Canon EOS 6D DSLR) to take pictures and time-lapses in order to complete the research work while aiding in its communication. However, on my last night I was given the opportunity to be the mission specialist on my first airborne sortie. My adrenaline was at its maximum as I sat in front of the dash with all those baffling buttons, and as we ascended the lack of oxygen and unpressurised cabin made operating my equipment a challenge. In spite of that the view was unbelievable, and successfully seeing noctilucent clouds from a totally new perspective was surreal; completely different from what I was used to back in Denmark.

Here's another view for your bucket list: the Northern Lights and NLCs combined

As an astrophotographer, getting to work with a team of such effectively trained astronaut candidates while testing a brand-new method of photography in a research field still in its infancy was the opportunity of a lifetime. Jason confided towards the end of the campaign that he was very optimistic that the data collected was scientifically valuable. Although half the campaign sorties were cancelled because of bad weather conditions, he told me, "We were able to assess and demonstrate a solid model of imagery collection for NLC tomography while pointing out a couple of setup improvements for the next campaigns.

"Both teams were really effective at operating the instrument as the crew resource management was optimal, and for many of the team members, this is as close to an actual space mission as you can get. This campaign will certainly help us get a better understanding of NLC structure and how the ice particles behave."

▸ **Adrien Mauduit reveals some of the secrets of photographing noctilucent clouds on page 84**

SKILLS

Brush up on your astronomy prowess with our team of experts

The Guide

With
Jamie Carter

A beginners' first steps into astrophotography

What you need – and need to know – to start taking your first astro images

The Andromeda Galaxy, captured with a Canon EOS 6D DSLR camera with a 500mm lens, an exposure of 193 seconds, f/6.3 and ISO 6400

The Horsehead Nebula taken using a Canon EOS 6D DSLR camera with a 600mm lens, an exposure of 130 seconds, f/6.3 and ISO 6400

Photographing the deep sky is now surprisingly easy. Armed with a DSLR (digital single lens reflex) or mirrorless camera on a tripod-mounted tracker, even novice astrophotographers can capture great shots of star clusters, nebulae, galaxies and other deep-sky objects.

This is thanks to a new generation of simple equatorial mounts designed for cameras rather than telescopes, which allow a simple tripod-and-tracker setup that's both affordable and portable. Let's explore this setup and photograph a star cluster, a nebula or galaxy! Here's the essential kit you'll be using:

The camera

You'll need a DSLR or mirrorless camera with a manual mode. Since deep-sky objects are faint, imaging them is about opening the shutter for as long as 90 seconds (in our setup) to allow as much light as possible to hit the camera's digital sensor. You'll also need a 38mm ball-head mount so that the camera can move independently of the tracker once it's in a fixed position.

The star tracker

Earth rotates fast – at almost 1,600km/h – and since we'll be taking long-exposure photographs, your camera needs to move in sync with the stars to prevent them from appearing as blurred trails on your photos. So you'll need a small EQ3 equatorial mount (about £150) or a lightweight tracker like the Sky-Watcher Star Adventurer or iOptron SkyTracker (about £250). "They're simple motorised equatorial mounts aimed at astrophotographers," says Allan Trow, manager at Dark Sky Wales (**www.darkskywales.org**), who teaches astrophotography workshops. "They're very portable and the polar alignment is easy." He suggests avoiding altaz mounts, which don't track the sky in a smooth motion. Sitting between a camera and a tripod, these trackers initially need to be aligned to Polaris, the Pole Star.

▼ **These setups show how the star trackers are positioned between the camera and the tripod when you want to do astrophotography**

ALLAN TROW/DARK SKY WALES, WWW.SECRETSTUDIO.NET X 2

The Milky Way seen from Pembrokeshire. Taken using a Canon EOS 6D DSLR camera with a 20mm lens, a 20-second exposure, f/2.5 and ISO 3200

The basics of taking your first photo of a star cluster, nebula or galaxy

CONDITIONS & LOCATION
Naturally, you'll need dark, clear skies, but astrophotography also requires good 'seeing' (a lack of atmospheric turbulence) and 'transparency' (a lack of the moisture and dust in the air that typically occurs after heavy rain). Perfect conditions will greatly improve your final photographs, but so will advice from experienced amateurs, so a good place to begin your astrophotography adventure is at your local astronomy club.

PREPARATION
You need to focus your camera and align the tracker. Finding the infinity focus point on your lens is best done before it gets dark by auto-focusing on something as far away as possible, using 'live view' to magnify the image. Mark where infinity focus is on your lens then switch it to manual focus.

Now you need to perform a polar alignment using the tracker's built-in polarscope, though its built-in spirit level is also important. "Always make sure the tripod is level otherwise your tracking will be out immediately," says Trow.

Now orientate the polarscope generally towards Polaris. Where exactly Polaris must be positioned on the tracker's polarscope clock face depends on your latitude and the time of night; free smartphone apps like Astro-Physics PolarAlign and Polar Scope Align will give you a simple visual guide.

Once that's done, lock the position of the tracker securely. You can then swing the camera towards your chosen deep-sky object.

CAMERA SETTINGS
All photography is about balancing aperture (which controls how much light reaches the image sensor), ISO (which controls the light sensitivity of the imaging sensor) and shutter speed/exposure time (which controls how long the image sensor is exposed to light). Start with an aperture as wide open as the lens goes (perhaps f/4.5 for a zoom lens or f/2.8 for a wide-angle lens). ISO 100 is used for bright conditions, so consider ISO 800 for astrophotography for more sensitivity, though ISO 1600 or 3200 may work better depending on how advanced your camera is. For the shutter speed, begin at 30 seconds and build up. Whatever your settings, it's crucial not to introduce camera shake, so use a remote shutter release cable, rather than pressing the button on the camera itself.

TAKING THE SHOT
For the likes of NGC 869 & NGC 884, M42 and M31 try a variety of settings and see what works best. If you're using a wide-angle lens, you could also try for a long exposure on the Milky Way in late spring and summer. Whatever you do, always shoot in RAW rather than JPEG so that you can use photo editing software such as Photoshop or Corel to produce a brighter, more detailed image. It makes a massive difference.

The lens

With a relatively basic star tracker, you can experiment with both wide-field and medium focal length DSLR lenses. What you use obviously affects magnification. That in turn affects the amount of blur in the finished photo; wide-angle lenses can be used for much longer exposures than telephoto lenses before stars begin to trail. The trackers we've mentioned can support anything up to about 600mm lenses.

Now aim for the stars

Three popular targets for beginners are the Perseus Double Cluster (NGC 869 and NGC 884), the Orion Nebula (M42) and the Andromeda Galaxy (M31). The all-in-one portable star trackers don't have built-in autoguiding software, though you can add an autoguider to any EQ3 mount. "It's not so important because most people go for objects they know to begin with, that they can find themselves," says Trow.

The easiest way to get great results without spending hours processing images is to take one, long-exposure photograph of your object of choice. Experiment with shutter speeds up to about 90 seconds. "With a 600mm lens, 90 seconds is as long as you'll get before stars start to trail, but that's more than enough for most deep-sky objects, particularly since newer cameras can bump up ISO," says Trow. Use a variety of settings – including different levels of white balance – and you'll soon learn what works best for different lenses and targets.

As you become more experienced, you may want to experiment with longer exposures, and 'stacking' your images to increase contrast, which means using more expensive equatorial mounts that are also more complicated to align. But armed with the relatively basic astrophotography setup we've described here, you can be taking stunning images in no time.

JAMIE CARTER is the author of *A Stargazing Program for Beginners*

INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

For inspiration, check out the great astrophotography on the Insight Astronomy Photographer of the Year website: **https://bit.ly/2HG9qvX**

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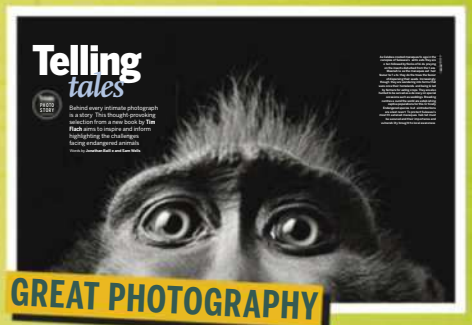
AMAZING STORIES



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How to...

With
Mark Parrish

Build a rotating eyepiece turret

A handy device to make swapping between your four favourite eyepieces easy

Oi, who are you calling four-eyes?

Visual observers habitually use a range of eyepieces, swapping between focal lengths to increase or decrease magnification or change the field of view. Fluctuations in seeing conditions during a session may also mean you need to swap eyepieces to get the best view.

This month's project aims to make the process a little bit quicker and easier, as we show you how to make a rotating turret that can hold up to four of your favourite eyepieces. It's a relatively simple matter to turn the carousel section around to select the best eyepiece for the target and saves you having to rummage around in your accessories box in the dark.

The job of an eyepiece is to magnify the image produced by your telescope's main 'objective' lens (or mirror). This telescope image is produced at a point that lies on an imaginary plain inside the focuser tube. Eyepieces have a similar focal point, inside the part of the tube that slips into the focuser. When these two points are brought perfectly together by turning the focuser knob (moving the eyepiece in and out) the result is a sharp, in-focus image. But eyepieces (even those made by the same manufacturer) usually have focal points at slightly different positions inside their tubes, so when you swap them around you often need to make small adjustments to bring the target back into focus.

It is possible to buy matched 'parfocal' sets with corresponding focal points but these can be expensive. Plus, most of us have built up collections of favoured but mismatched eyepieces over the years. So we've designed our turret to grip your eyepieces at varying levels in the carousel meaning that they're all in focus as soon as they're rotated into position. This is a real benefit when switching between views, perhaps when scanning an area of sky at low power before 'zooming in' with a higher magnification.

One consideration when embarking on this project is the extra weight being ▸

ALL PICTURES: MARK PARRISH

TOOLS AND MATERIALS

TOOLS
Jigsaw (or coping saw), drill and bits (1.25-inch or 32mm for eyepieces plus 5.5mm and 6mm for other holes and 11mm for nut inserts)

MATERIALS
Small sheet of good-quality plywood approximately A4 size (we used 15mm thickness but 12mm or 18mm may suffice)

SUNDRIES
Five M6x30 nylon screws with normal M6 nuts; one M6x50 screw with a nyloc nut and three M6-threaded penny washers; a 1.25-inch tube approximately 30mm long (we recycled part of an inexpensive T-ring adaptor); various parts from a plastic, retractable ballpoint pen; a round-headed map pin

COVERING
Some spray paints or wood varnish to provide a good finish

▸ introduced to the focuser. Four eyepieces in themselves obviously create an additional load, but the materials used in the turret also need to be taken into account. Many telescopes are used for imaging purposes and if yours can support a DSLR camera then it should be able to cope with this turret without any fuss. Certainly, if you have a focuser with a 2-inch drawtube you should be fine. You also need to make sure your focuser can move inwards by about 45mm from its normal 'in focus' position to account for the thickness of the plywood layers.

You know the drill

In our design we cut away much of the carousel disc to minimise the weight. You may wish to make further reductions by removing material elsewhere but make sure you leave enough surrounding the eyepiece screws and maintain a smooth circumference for the carousel. Make a shallow saw cut into the circumference next to each eyepiece hole for the locator.

We were fortunate to have a 1.25-inch bit to drill our eyepiece holes but if you don't have one to hand you can buy relatively inexpensive flat bits and hole saws in this size or, alternatively, you can drill a series of small holes around the circumference of the hole (chain drilling) and get to work with a rasp or file.

We chose nylon eyepiece screws to avoid scratching the tubes but a normal screw with a smoothly sanded end should be okay. These screw into threaded inserts made with N6 nuts. Plans for how to make a spring-loaded position locator which lets you know when each eyepiece is lined up can be found in the online Bonus Content for this issue (see page five).

We would recommend setting up your favourite four eyepieces on a distant target in daylight, adjusting them so they all come into focus at a similar height; just make sure each is gripped securely with the retaining screw so there's no danger of it slipping out. You may consider adding a second screw to each holder at 90 degrees to the first (as is the case with some focusers) if you want a 'belt and braces' solution.

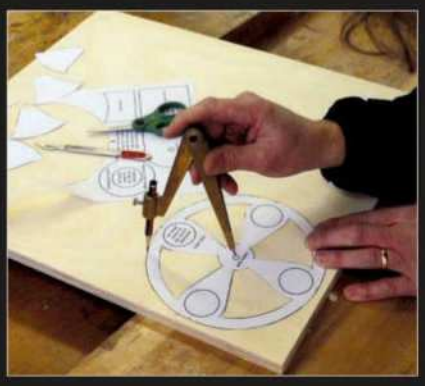
MARK PARRISH is a consummate craftsman. See more of his work at his website: buttondesign.co.uk

YOUR BONUS CONTENT

Plans, blueprints and additional images can be found in our online section

ALL PICTURES: MARK PARRISH

STEP BY STEP

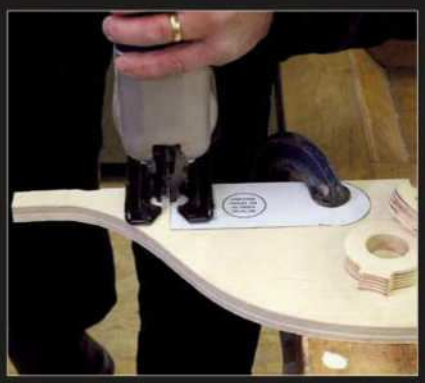


STEP 1

Print out the downloadable template (see below left) and use it to carefully mark out the plywood sections. Cut out each paper section and draw round it. It is a good idea to use a sharp point to mark through the centre of each hole to aid accurate drilling.

STEP 2

It is easier to clamp regular-shaped, larger pieces of wood when drilling the eyepiece holes, so we drilled most of ours before cutting out the small shapes. A pillar drill ensures a vertical hole but with care this can be done by hand.



STEP 3

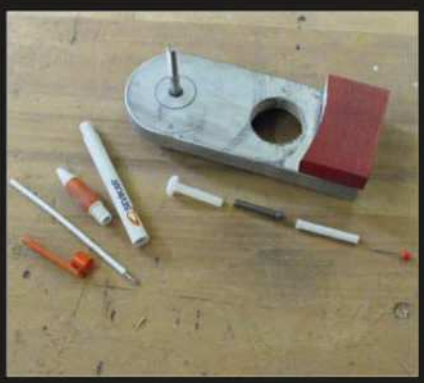
Clamp the wood to the bench or use a vice when cutting out the plywood shapes. We used a jigsaw, but a variety of other tools can accomplish the task. A less-than-perfect shape won't really affect the performance if the parts are smooth.

STEP 4

Before drilling right through each eyepiece holder with a 6mm drill, make 11mm diameter holes in which the nuts will be inserted. We squeezed the nuts into these holes with a small clamp after applying some epoxy resin glue.

STEP 5

After carefully sanding the parts and checking the threads and holes are all fine, it is time for painting. After applying a good coat of grey primer, we used a variety of spray paints. The finish protects the wood from moisture.



STEP 6

Use the parts from a ballpoint pen to make a spring-loaded locator. In use, a map pin presses against the circumference of the carousel. As the carousel turns, the pinhead clicks into saw cuts next to each eyepiece indicating that the eyepiece is lined up.

Image PROCESSING

With **Adrien Mauduit**

INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

Advice from a 2017 shortlisted Skyscapes entrant

IAPY masterclass:
Noctilucent lines of perspective

For the best results, processing your NLC photos is all about subtlety with the settings

Noctilucent clouds over Ordrupnæs, a peninsula of the Odsherreds area of Denmark

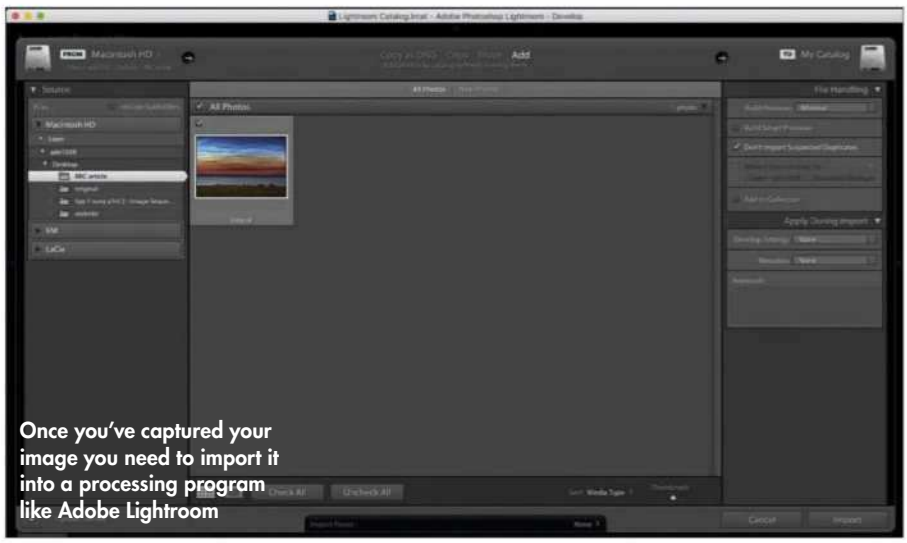
Despite the shorter, brighter nights, the summer skies are far from dull and can offer some remarkable subjects to photograph, including night shining, or noctilucent, clouds (NLCs – see pages 64 and 72 for more about these fascinating displays). Here we cover how you can easily take, process and produce stunning shots of noctilucent clouds in rather dim and backlit situations to correctly emphasise the details in their silvery tendrils without blowing out the highlights.

NLCs evolve rather slowly and the twilight gives you enough light to adjust your camera settings depending on your camera's and lens's abilities. Once your gear is set up, use the manual setting to set focus at infinity on a bright source of light in the far background (a star or a streetlight): if your camera has live view, use its built-in zoom. Since NLCs occur in a half-light situation, your main challenge will be to get the best dynamic range; in other words, not blowing out the highlights above the horizon while conserving enough data in the shadows to avoid noise!

The example picture in this feature was taken with a Sony α7R II camera and a Canon 100mm f/2.8 lens with a shutter speed of three seconds to avoid motion blur while gathering enough light. The aperture was stopped down to 3.2 to increase sharpness and an ISO of 400 achieved good light levels and minimised noise. We recommend you take several shots at different settings to improve your chances of getting the right exposure.

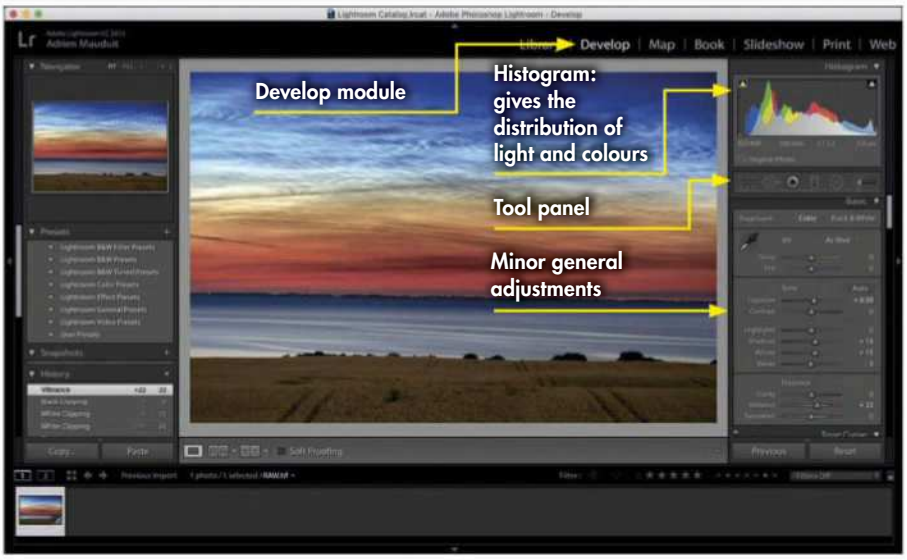
Setting the settings

Once back at home, import the RAW pictures from your SD card into your image processing software; we used Adobe Lightroom. Head over to the 'Develop' module (Ctrl+D) and start preliminary general adjustments. The right-hand side panel acts as a tool box and helps you adjust just about every setting. We generally go through the adjustment sliders from top to bottom. Consequently, start by slightly adjusting the white balance



Once you've captured your image you need to import it into a processing program like Adobe Lightroom

ALL PICTURES: ADRIEN MAUDUIT



▲ The first stage of processing for this image was done in Adobe Lightroom's Develop module

▲ A feathered brush is used to mask off the foreground, the masked areas becoming red

but try and keep the colours as natural as possible; raw twilight photos tend towards blue in temperature and pink in tint, so you may need to nudge your 'Tint' and 'Temperature' sliders the opposite way. Bump up the general 'Exposure' slider until the shot's correctly exposed without blowing out the highlights. That might cause you to lose the fine structure in the clouds. So play with the 'Whites', 'Blacks', 'Shadows' and 'Highlights' sliders to get the best distribution of light.

The latter can be visualised in the histogram in the upper-right corner. You want a histogram that is spread out and drawn slightly to the left, but none of the lines should vanish off the top of the graph. In the example we increased the exposure to +0.5, the shadows to +15, the whites to +15 and lowered the blacks to –3.

The goal is really to do minor general adjustments to keep a balanced and natural look, so use these sliders carefully. We would recommend you leave 'contrast and clarity' for local adjustments later. Increase the vibrancy a bit (don't go over +25) but avoid using the master saturation button just yet. Head down to the 'HSL/Saturation/B&W' slider and you can increase each colour channel to your liking, especially reds, oranges, yellows and blues to get a nice twilight gradient. Be careful not to oversaturate by staying below 25. Further down, apply a general dose of luminance noise reduction from +10 to +25 and you can also sharpen a tad (+25).

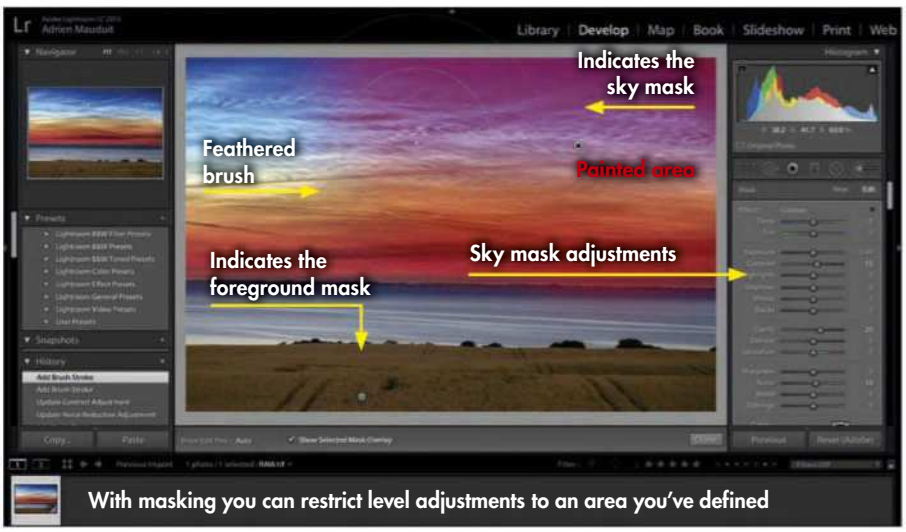
Finer adjustments

Now use local adjustments to enhance only selected sections of the image. The 'Adjustment Brush' tool can be found in the right-hand column panel. Apply the first mask by roughly painting out the foreground with a feathered brush. The mask will appear red so you can see the area the adjustments will be applied to. The adjustments sliders for the mask will automatically appear in the right-hand side panel. Bump up the exposure (+0.1), shadows (+5) and blacks (+5) slightly while reducing the contrasts (–15) to light up the foreground a notch. Remember to apply some noise reduction as well (+25).

Next draw a second mask for the sky only. In this one you want to make the noctilucent cloud structure pop out. Increase the contrasts (+20) and the clarity (+25). Finish by applying a slight noise reduction (+5 to +10).

When you're satisfied with the result, click on 'file>export' then select your output location and the quality setting. We advise you to export two pictures: one as a TIFF to conserve as much quality as possible, and another as a JPEG, which is better for sharing on social media. Because everybody loves a great NLC shot.

ADRIEN MAUDUIT is an aurora-chaser, astrophotographer and science educator



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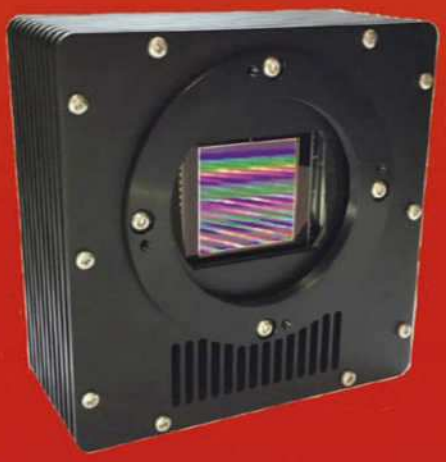
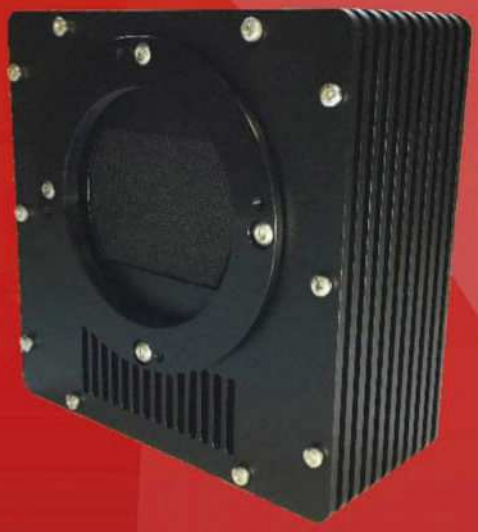


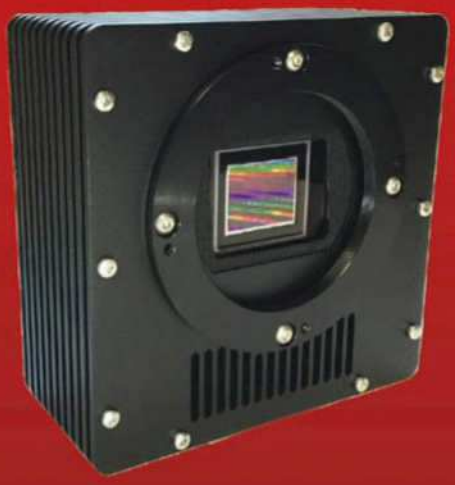
Introducing a new and exciting range of large format CCD cameras from Starlight Xpress. Utilising the new KAF16200 16M pixel APS format CCD and the renowned large KAF16803 16M pixel CCD sensor. The new TRIUS SX-46 and TRIUS SX-56 bring large format imaging to your optics.

Rolling-blind Shutter



Designed and manufactured in-house, this rolling-blind shutter allows for shorter exposure times and significantly shorter flat-field exposures.

TRIUS SX-46



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- **3 stage cooling (-50C delta)**
- **Sapphire AR coated window**
- **Built-in RBI-Flash**
- **Light-weight (1.7Kg)**
- **Low read noise**
- **Argon filled CCD chamber**
- **Low power**

Built-in 3 port USB hub

For further information, please take a look at

www.sxccd.com

Scope DOCTOR

With **Steve Richards**

Our equipment specialist cures your optical ailments and technical maladies

I am the owner of a second-hand 10-inch Newtonian. Despite cleaning the mirror with distilled water, mild detergent and alcohol it is still quite dull. Should I have it recoated?

KARI BROWN

In general, more modern mirrors will very rarely require re-coating but so much depends on how they have been looked after, and there is certainly no standard length of time you should adhere to. It is not at all uncommon for coatings to last 30 years or more.

The main causes of mirror damage are constant exposure to moisture, contaminants through poor storage and, ironically, cleaning them too often. A Newtonian mirror will very rarely require a clean unless it's been woefully neglected and even then it should only be cleaned with a very mild detergent and washed off with copious amounts of distilled water.

Taking a look at the photograph of your mirror surface, the finish looks pretty acceptable and there are no black spots, which often indicate that the surface is failing. The surface does have some fine scratches but unless these are producing obvious artefacts around bright stars, even these shouldn't be an issue. They are, however, a reminder of the danger of over-zealous cleaning.

A well-illuminated, close-up photograph of a mirror such as the one you sent to us will tend to exaggerate any imperfections in the surface anyway, and so cannot be relied on for assessing the true state of the reflective coating. However, if you shine a light from behind the mirror and can see lots of pinpricks on the surface this would give an indication that the surface is nearing the end of its life and you should consider having it recoated.

► If you think your primary mirror needs a clean, it's probably near the end of its life

PAUL WHITFIELD, STEVE RICHARDS

▲ Just don't get it mixed up with your sandwich box

I tend to struggle finding the eyepiece I need in the dark. Any advice for keeping them organised?

LEON SPENCER

Having a range of eyepieces outside with you allows you to observe a greater number of different objects during an observing session. You certainly don't want to risk losing your dark-adapted vision by having to go inside to collect a new eyepiece.

It helps to start with a longer focal length eyepiece to locate your object and then use shorter focal lengths until you reach the optimum magnification for each object. With this in mind, placing your eyepieces in focal length order is the obvious way to proceed. Many telescope mounts have eyepiece receptacles built into them but there are rarely enough holes for most observers' collections. However, a simple eyepiece sorter can be made using a plastic food container filled with 'pick and pluck' foam suitably crafted to house your eyepiece collection. Alternatively, this month's *How To…* project on page 81 might offer a solution.

STEVE'S TOP TIP

What's the deal with Plössl eyepieces?

A Plössl eyepiece comprises four glass elements arranged as two back-to-back achromatic doublets; or, in other words, two pairs of two glass lenses. These eyepieces produce a 'standard apparent field of view' of between 50° and 56° with most set at around 52°. This general purpose design gives good colour correction and an adequate field of view at reasonable cost and they are often bundled with new telescopes.

On the downside, Plössls, especially at shorter focal lengths, suffer from short eye relief – a measure of how close to the eyepiece you have to place your eye to see the full field of view.

STEVE RICHARDS is a keen astro imager and an astronomy equipment expert

Email your queries to scopedoctor@skyatnightmagazine.com

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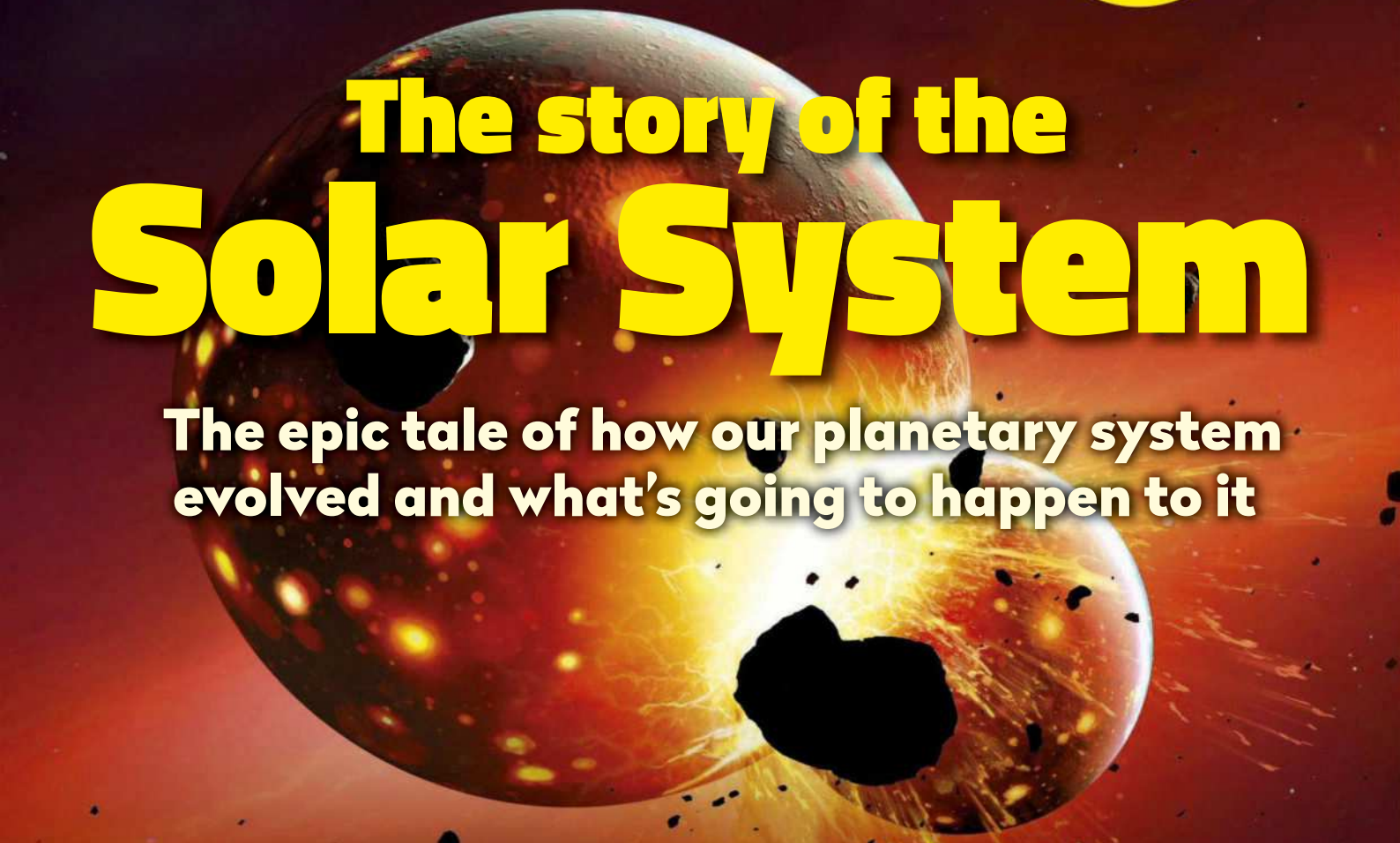

MARK GARLICK

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BBC Sky at Night MAGAZINE

Reviews

Bringing you the best in equipment and accessories each month, as reviewed by our team of astro experts

HOW WE RATE

Each category is given a mark out of five stars according to how well it performs. The ratings are:

★★★★★ Outstanding
★★★★½ Very good
★★★½☆ Good
★★½☆☆ Average
★½☆☆☆ Poor/Avoid

This month's reviews

FIRST LIGHT

90 Celestron Astro Fi 5 Schmidt-Cassegrain Wi-Fi system

94 Avalon M-Uno Fast Reverse Go-To mount

98 Atik Horizon CMOS camera

BOOKS

102 Jupiter through the ages, a travel guide to the Solar System and more

GEAR

104 All the latest kit, including a satellite-tracker and Mars marbles

Find out more about how we review equipment at **www.skyatnightmagazine.com/scoring-categories**

SEE INTERACTIVE 360° MODELS OF ALL OUR FIRST LIGHT REVIEWS AT WWW.SKYATNIGHTMAGAZINE.COM

94

Red alert! The Avalon M-Uno's elegant, industrial design is perfectly matched by its sturdy functionality

FIRST LIGHT

See an interactive 360° model of this scope at **www.skyatnightmagazine.com/AstroFi5**

Celestron Astro Fi 5 Schmidt-Cassegrain Wi-Fi system

WORDS: PAUL MONEY

Let your smartphone be your guide with this easy-to-use mount for beginners

VITAL STATS

- **Price** £599
- **Optics** 127mm SCT compound
- **Focal length** 1,250mm, f/10
- **Mount** Wi-Fi Go-To altaz single-arm mount
- **Ports** Power connector, two aux ports, integrated Wi-Fi adapter
- **Tracking Rates** Sidereal, lunar, solar tracking
- **Tripod** Adjustable tripod with accessories tray including rubberised smartphone holder
- **Extras** StarPointer red dot finder, 25mm and 10mm 1.25-inch fit eyepieces and star diagonal
- **Weight** 7kg
- **Supplier** David Hinds Ltd
- **Tel** 01525 852696
- **www**.celestron.uk.com

SKY SAYS...
A decent system for beginners controlled by smartphone, the Astro Fi 5 fulfils its function well

Once upon a time, viewing the night sky involved carefully setting up and aligning your telescope, then manually rotating the scope to point it at your target. Then powered mounts arrived to make things easier, after which along came Go-To mounts with their sophisticated handsets and several thousand objects in their databases. Now even they feel like antiques as smartphone controlled telescopes are becoming the new norm. So here we look at Celestron's Astro Fi 5, a Wi-Fi-controlled system for modern times.

The system comprises a 5-inch (127mm) Schmidt-Cassegrain telescope on a single fork arm with integrated Wi-Fi, attached to an aluminium tripod. The telescope has a focal length of 1,250mm giving a focal ratio of f/10, which means this is considered a 'slow' system, best suited to observing planets, lunar and bright deep-sky targets. It looks very smart in its Astro Fi livery while the optical surfaces come with Celestron XLT multi-coatings for a crisper quality view.

Easy to set up

The single fork arm has a Vixen-style mounting saddle to which you attach the telescope using a chunky restraining bolt; it was pleasingly easy to install on the tripod. A padded power pack, which takes eight AA batteries (not included), is provided and you can also use an optional power tank. The power switch has a small red LED to indicate when the system is on, which is handy.

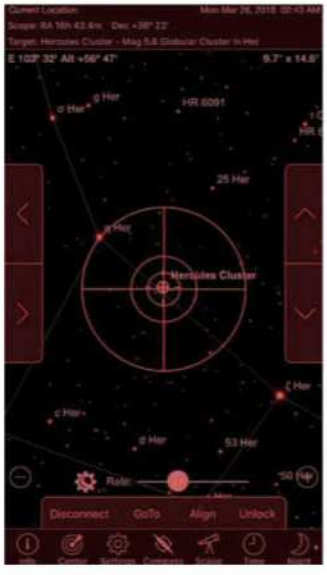
A StarPointer red dot finder, star diagonal and two eyepieces complete the system. With a focal ratio of f/10 the 25mm eyepiece gives a magnification of x50 while the 10mm eyepiece provides x125, a good range for the kind of targets you'd use this system for.

We powered up the mount, the connected to the inbuilt Wi-Fi with our smartphone via the ▸

Wi-Fi and the SkyPortal app

The Wi-Fi/smartphone control of the Astro Fi 5 system worked well every time we connected. The SkyPortal app is available for iOS or Android from the respective stores. Installation is very fast. Power up the mount and it automatically sets up a Wi-Fi spot which you can connect to. We used both our iPhone 6S+ and iPad Pro to connect with no fuss.

Open up SkyPortal and chose 'connect and align' and follow the onscreen instructions to align on three stars. Once successful you can use the app to explore any of the targets or manually slew the telescope using the onscreen arrows. You can even use your smartphone's compass to aim at any target to get the telescope to slew across to view it. Overall the pointing accuracy was good with all targets appearing in the 25mm eyepiece's field of view.



WWW.THESECRETSTUDIO.NET X 4, PAUL MONEY X 2

Optics

The Astro Fi 5 is a Schmidt-Cassegrain telescope comprising a primary mirror and a corrector plate with the secondary mirror attached to the corrector. It has a 'long' focal length of 1,250mm giving a focal ratio of f/10, although strictly speaking it works out at f/9.8. All optical surfaces are multicoated.

Single arm mount

The single arm mount holds the electronics and gears and is very solid in build quality. The mount has a Vixen-style saddle for attaching the telescope, with a good, chunky retaining bolt giving a solid grip to the Vixen bar on the telescope.

Tripod

The tripod has aluminium telescopic legs that can be extended and was sturdy to use. The mount affixes very easily with a single underside bolt from the tripod which holds it firmly in place. The spreader tray can hold two 1.25-inch eyepieces and there is a rubberised smartphone holder.

Accessories

The StarPointer red dot finder worked well for aiming the telescope, especially during alignment. Two eyepieces are provided, 25mm and 10mm, which give magnifications of x50 and x125 along with a 90° star diagonal. The eyepieces gave good views of all our targets but especially of the planets and the Moon.

FIRST LIGHT

▲ Tycho to Clavius and the lunar South Pole, taken at full-frame view on a ZWO ASI 224C CMOS camera using 500 stacked frames

▸ SkyPortal app and were soon aligned using the on-screen instructions. With the 25mm eyepiece in place we slewed to Regulus in Leo finding the star pin-sharp across almost all the view with only slight distortion at the edges. We could easily see Regulus and its companion as it is a wide system, so we then aimed for Algieba, a lovely and closer golden pair of stars that just split in the 25mm.

Swapping to the 10mm lens made them a lovely sight indeed. This inspired us to take a look at Castor, another close system that actually has a third companion, viewable when we dropped back down to the 25mm.

Target practice

We caught M42/43, the Orion Nebula, just before it set over the horizon, enjoying its wealth of nebulosity while having a good view of the Trapezium stars at the centre. The supernova remnant M1, the Crab Nebula, was a lovely oval glow at both magnifications while the Eskimo Nebula, NGC 2392 – which is a planetary nebula – was small but a faintly greenish blob even in the 10mm eyepiece.

Turning our attention to the deep sky we found we could just fit the wonderful galaxy pair M81/M82 in the view of the 25mm. M81 was a pale oval, while using the 10mm we could see a subtle mottling along the sliver that is M82 – nice! We tried for NGC 2903, which is a bright galaxy in Leo, but surprisingly we couldn't find it in the SkyPortal app. We could have connected via our Sky Safari v6 app, which provides even more targets, but to be fair to the SkyPortal app, it does cover the main Messier and Caldwell objects along with a searchable list of popular named targets including the main Solar System objects.

Once the Moon was available we enjoyed a wealth of detail with the 25mm lens giving a full-disc view and the 10mm giving great close-up views of craters such as Tycho and Clavius. The only easily viewable planet for us that night was Jupiter later in the evening, and we were rewarded with views of the gas giant's two main belts, polar hoods and all four of its Galilean moons.

The Astro Fi 5 is a decent system aimed at beginners who want to enjoy the night sky using their smart devices. It certainly managed to fulfil its criteria and can be recommended. S

▲ The double stars Algieba (top) and Castor (above) taken on a ZWO ASI 224C CMOS camera, with a stack of 200 frames for each image

Verdict

Assembly	★★★★★
Build and design	★★★★☆
Ease of use	★★★★☆
Features	★★★★☆
Optics	★★★★☆
OVERALL	★★★★★

SKY SAYS...
Now add these:

1. PowerTank Lithium
2. Observer's accessory kit
3. 40mm Plössl eyepiece

FIRST LIGHT

See an interactive 360° model of this mount at www.skyatnightmagazine.com/Avalonm-uno

Avalon M-Uno Fast Reverse Wi-Fi Go-To mount

WORDS: NICHOLAS JOANNOU

A sturdy mount that combines design and function into an object of beauty

VITAL STATS

- **Price** mount: £5,199 tripod: £699
- **Load capacity:** 20kg on each side of the dec. axis
- **Hand controller:** Basic controls, direction, speed and focus; these and other functions are also via wireless interface
- **Database:** Dependent on planetarium software used
- **Flash upgradeable:** Control software upgradeable online
- **Autoguider port:** ST4
- **Wireless control:** Internal Wi-Fi connecting to StarGO system
- **Weight:** mount: 15kg tripod: 6.8kg
- **Supplier:** The Widescreen Centre
- **Tel:** 01353 776199
- **www.**widescreen-centre.co.uk

SKY SAYS...
It simply oozes quality and capability when in motion. The attention to detail is outstanding

The Avalon M-Uno Dual Fast Reverse mount is an upgraded version of the well-regarded M-Uno mount. It is designed primarily for deep-sky imaging, aimed at the higher end of the market with the intermediate to advanced astronomer in mind. Introduced to the mount is a new, fully rotating, dual declination (dec.) axis that gives you a variety of mounting and clamping options for one telescope or two at once, including the ability to mount and accurately align a guidescope with the main telescope.

The attention to detail, function and style on this mount is outstanding. From the smallest to the largest, every single component is beautifully machined, well thought out and put together with the best of materials – there are no cut corners here.

The high-quality, low-friction internal bearings on both axes perform well. Even under heavier loads the mount moves extremely smoothly, making the balancing process easy. Just as smooth in operation are the pleasantly quiet motors that use a tooth-belt transmission of power to the axes, making them backlash free and responsive to use.

Surprisingly light

Other than the popular choice of a short tube refractor for imaging, the 20kg payload of the mount and an easily adjustable fork arm allow for larger telescopes – such as Ritchey-Chrétiens, Schmidt-Cassegrains or Riccardi-Honders – to be happily used for both observing and photography, while still being well under the maximum capacity of the mount. Even with all its payload-carrying capability and relatively large mount head, the M-Uno Dual is still light for its size and easy to carry and transport, with all major components having well-placed handles. The design also means you don't need hefty counterweights for balancing, which is very welcome compared to traditional German equatorial mounts.

Setting up is quick and easy. When pulled open, the tripiod locks its spreader into place, stabilising ▸

Unique mount design

The M-Uno is a mount that has been designed from the ground up with great independence of thought. The engineering of the mount eliminates many technical problems, both in terms of each individual part doing its job well and the sum of those parts working perfectly together. Seemingly every part has been meticulously designed to fit in seamlessly with the function of the mount's systems as a whole.

One of the more striking examples of this is the unique shape and movement of the mount head which, when paired with most telescopes, eliminates the need for counterweights and – unlike standard equatorial mounts – can track uninterrupted through any portion of the sky without needing to do a meridian flip. All of which is achieved using lightweight materials, expertly crafted to high tolerances, giving you a mount that is at once powerful, accurate and sleek. All this function in the design is then beautifully and aesthetically finished, making it a real joy to look at and to use. It simply oozes quality and capability when in motion.

ALL PICTURES: WWW.THESECRETSTUDIO.NET

Wireless control

The mount is primarily designed to be controlled using the strong and reliable internal Wi-Fi or Bluetooth connection. This connects to the highly customisable Avalon StarGO software with the ASCOM software platform running in the background when on a PC. It can also connect to smartphones and tablets.

Tripod

The gorgeously anodised, large and stable tripod is fast and easy to set up. It's made using high-grade aluminium, making it light to carry, and features an incorporated handle. On the legs are a number of 2-inch and 1.25-inch openings that help lighten the tripod and conveniently hold eyepieces and other equipment as well.

Polarscope

The M-Uno comes with a well-made polarscope allowing you to polar align with ease and comfort without having to disturb anything else on the main mount. The polarscope is quickly and easily illuminated with a slip-on unit powered from a dedicated socket tucked away on the mount.

FIRST LIGHT

Dual mountings

The M-Uno has the ability to dual mount equipment on the dec. axis. The unit tested, for example, was fitted with the larger Losmandy-style clamp on the upper section and the smaller Vixen-type clamp on the lower. This allows for great flexibility and customisation of payload for visual and/or photographic use.

▸ the legs. It attaches to the main mount using three bolts at the top, instead of the more usual large central bolt and spreader combination from the bottom. The accurately CNC-machined main body of the mount has an ST4 guide port as well as a DSLR control port, and can track across the meridian in a single motion without performing a meridian flip, a great feature for long-exposure imaging. All of the clamps and manual controls are securely made and smooth to operate, holding everything in place with confidence and are designed to be easy to use even if you're wearing gloves. All motor connection cables are internal to reduce operational interference and give the mount a sleek and uncluttered look.

Extras

This well thought-out mount comes with a very useful set of well-made extras that will come in handy for transportation and set-up. Especially good are the small, neat counterweights with miniature extension bars and a removable carry handle for the mount head that balances the load perfectly.

Smooth operator

The controls for polar alignment feel light and smooth to use, adding to the speed and accuracy of the setup. With the tolerances of the mount being so tight, it was no surprise to see that damping times for vibration in the eyepiece or camera were very short when tested. All of the software needed for setting up, manuals and videos are conveniently stored on a chrome and leather-bound USB stick. Once you've installed the relevant applications on your laptop, the wireless connection process is easy and the signal strong. It's also possible to connect using other Wi-Fi or Bluetooth devices such as smartphones or tablets adding to the versatility of the mount. Using the StarGO navigation system is simple and instinctive to use, the graphical interface proving to give accurate Go-To commands as well as having an easy alignment process.

The tracking accuracy was tested using a 9.25-inch SCT telescope by leaving a bright star in the centre of the field of view of a 25mm Plössl eyepiece and checking for drift over a period of time. When set up well, the subject was still within the field of view after one hour's wait and could well have stayed there much longer.

We could sing this mount's praises all day long, but we'll simply wrap up by saying that the Avalon M-Uno Dual Fast Reverse effortlessly succeeds in its aim to be powerful, smooth, stable, beautiful, functional and transportable. It's rare to find such a complete product. S

Verdict

Assembly	★★★★½
Build and design	★★★★½
Ease of use	★★★★½
Go-To accuracy	★★★★½
Stability	★★★★½
OVERALL	★★★★★

SKY SAYS...
Now add these:

1. Choice of dual mounting attachments, either Vixen or Losmandy style
2. Bracket for external use of polarscope
3. Avalon X-Guider

ALL PICTURES: WWW.THESECRETSTUDIO.NET

FIRST LIGHT

See an interactive 360° model of this camera at www.skyatnightmagazine.com/atikhorizon

Atik Horizon CMOS camera

WORDS: TIM JARDINE

Atik's first CMOS camera offers a versatile sensor for smaller scope users

VITAL STATS

- **Price** £1,219
- **Sensor** 16 megapixel Panasonic MN34230 4/3-inch CMOS (colour)
- **Quantum efficiency** 50 per cent @ x1 gain
- **Max cooling** –40°C below ambient
- **Min exposure** 18 milliseconds
- **Max exposure** Unlimited
- **Connectivity** USB 3, USB 2
- **Size** 13cm x 7.4cm
- **Weight** 517g
- **Supplier** www.atik-cameras.com
- **Tel** 01223 727144
- **www.**atik-cameras.com

The technology behind digital photography is constantly advancing and there's always something new on the horizon. Camera sensor manufacturers are moving away from CCD designs in favour of cost-effective CMOS sensors. In line with this trend, Atik Cameras has introduced its first CMOS-based, deep-sky astronomy camera, the aptly named Atik Horizon.

SKY SAYS... With adjustable sensitivity and low noise this is the future of photography at a tempting price

The camera is available in two formats: one-shot colour (OCS) and monochrome. Our review model was the OCS. While additional filters aren't required, we find that IR filters benefit the colour balance and saturation of OSC cameras in general, so we attached one to the camera, and mounted it to our refractor.

The Horizon comes with a full software suite, including Artemis Capture imaging software. But with a relatively short window for testing, we opted to use the included ASCOM driver for most of our targets, which enabled us to use our more familiar observatory software with the camera.

The Horizon, in common with other CMOS devices, offers an adjustable gain setting. Atik explains this as being similar to turning up the volume on a radio, bringing out fainter details at the expense of stronger signals. A full appraisal of the gain setting is not possible here – it takes even Atik over 13 minutes to explain the concept in this handy, if very technical, YouTube video: **https://bit.ly/2KlrFrI**.

For monochrome cameras, the advantages of using higher gain settings are more clear-cut, but we tested the three available preset options via the ASCOM driver: low, medium and high, or x1, x5 and x30 respectively. Although the higher gain settings offered very low read noise, for our tastes the colour camera produced the most appealing pictures with the low gain setting.

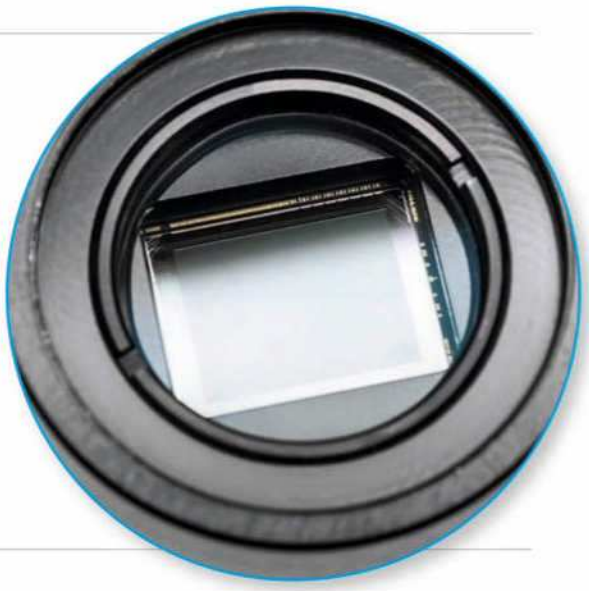
Practical testing

Once settled on this option we set about capturing photographs of some prominent deep-sky targets, including the high dynamic range Orion Nebula, and the famous M65, M66 and NGC 3628 galaxy triplet in Leo. To see how the Horizon handles a combination of faint and bright stars and different ▸

A powerful sensor

CMOS cameras are gradually shaking off their early reputation as a noisier, less desirable alternative to a CCD-based device. The Panasonic MN34230 sensor used in the Horizon goes further, and with Atik's custom electronics, designed in-house, it actually has a lower read noise at high gain than CCD cameras. The 16 million pixels are arranged in a 4,644 X 3,506 array, and are 3.8 microns square, with a quantum efficiency of 50 per cent.

This makes the camera especially suitable for smaller, short focal length telescopes, – perhaps a 3-inch or 4-inch refractor, or even camera lenses – and it is best-suited to high resolution, wide-field astrophotography. The colour Horizon variant will appeal to those who want a simple, filter wheel-free imaging system, and will provide optimal results on apochromatic telescopes. Using higher gain settings allows you to take relatively short exposures – an appealing factor for setups with limited sky tracking capabilities – but suitable targets should be carefully selected when using higher gain settings on the colour version.



ALL PICTURES: WWW.THESECRETSTUDIO.NET

Software

No need to buy extra software, as the Horizon is fully supported in Artemis Capture, and images can be processed using Dawn. In addition, live view and on-the-fly image stacking is available using the Infinity application, and you can even live broadcast the camera view on YouTube. The software is available on the CD provided or downloadable from **www.atik-cameras.com/downloads/**.

Size, shape & design

With solid aluminium construction, the camera weighs in at a touch over 500g. It's 13cm in length without a nosepiece, and about 74mm in diameter. This makes it suitable for HyperStar imaging, especially the OSC version. Back-focus from the M42x0.75 female thread at the front is 13mm.

Sealed chamber with desiccant

The CMOS sensor chamber is efficiently sealed with fused quartz glass. We experienced no issues whatsoever with condensation either inside or outside the chamber, even on really humid nights, working at –20°C. A replaceable desiccant is included as an additional defence against frost and ice issues.

Cooling and power

The camera requires a separate 12V DC supply, not provided, to power the camera and the thermo-electronic cooling system, which is assisted by the large heat sink and the powerful, but quiet, rear fan. We found the set point cooling to be very stable during large drops in ambient temperature.

FIRST LIGHT

SKY SAYS...
Now add these:
1. Atik universal power supply
2. Atik off-axis guider
3. Atik GP guide camera

▸ star colours, we also checked out M13, the large globular cluster in Hercules, which is home to a combination of blue, gold and white stars.

The detail revealed in the galaxies was impressive. The colour within even brighter stars was well controlled on the low gain setting, and it was quite exciting to pick out even tiny, faint, fuzzy galaxies in the background of the Leo Triplet. The Orion Nebula exposures demonstrated the Horizon's sensitivity to emission nebulae wavelengths. The results of the M13 exposures also impressed us, truly revealing the star colours within the cluster.

Speedy connections

The download speed from the camera to PC is pleasingly fast – especially given that the individual frames are 31MB each and that we used our existing USB 2 connections. The efficiency improved even more when we connected the Horizon using the USB 3 cable, which demonstrates the benefit of 256MB of onboard memory. The fast download times helped to smooth out the framing and focusing procedure, which can sometimes be tedious on high resolution cameras.

We were keen to test the efficiency and stability of the Horizon's cooling system, as properly matched temperatures on dark and calibration frames can make all the difference in eliminating the effects of amp glow and other unwanted noise artefacts. We set the cooling to –20°C, which is 30° below the ambient temperature. The temperature of the sensor dropped rapidly to just below the target and stabilised after a minute or two at –20°C, reliably maintaining this temperature throughout successive sessions.

With CMOS sensors establishing themselves as the future of photography, Atik's Horizon is a solidly built, highly capable imaging device with low read noise and adjustable sensitivity, all at a tempting price point. S

Verdict

Build and design	★★★★½
Connectivity	★★★★½
Ease of use	★★★★½
Features	★★★★½
Imaging quality	★★★★½
OVERALL	★★★★★

▲ M42 captured using nine five-minute exposures with the camera set on low gain

◂ M51 captured using 38 two-minute exposures at high gain, demonstrating how high gain might be useful for targets with low dynamic ranges

Electronic shutter

There is no mechanical shutter covering the sensor; exposure control is accomplished electronically. While this does make it easier to take short exposures for flat frame calibration files, you'll need to enable the 'Even Illumination' setting in the ASCOM camera driver to ensure that there is no visible gradient on very short exposures.

WWW.THESECRETSTUDIO.NET, TIM JARDINE X 2

Books

New astronomy and space titles reviewed

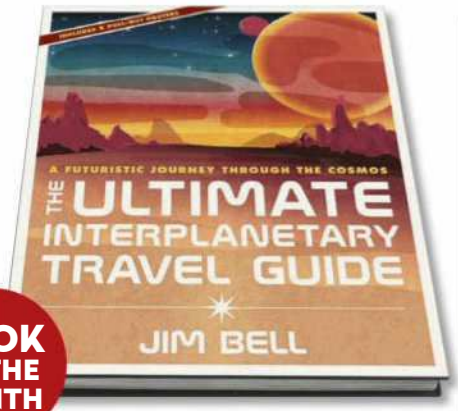
RATINGS

★★★★★ Outstanding
★★★★☆ Good
★★★☆☆ Average
★★☆☆☆ Poor
★☆☆☆☆ Avoid

The Ultimate Interplanetary Travel Guide

A Futuristic Journey Through the Cosmos

Jim Bell
Sterling
£19.99 ● HB



BOOK OF THE MONTH

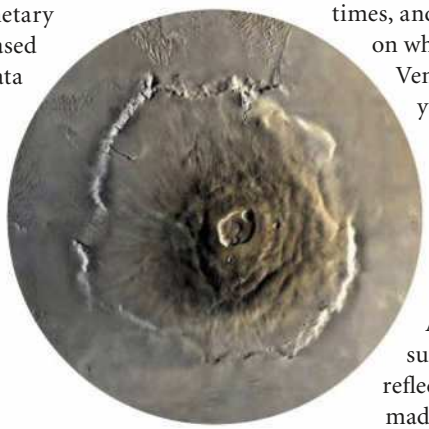
The first aeroplane flew a little over a century ago, and today it seems that the sky has no limit at all. With hundreds of prepaid tickets for suborbital spacecraft rides already sold, humanity is taking its first steps toward space tourism.

The Ultimate Interplanetary Travel Guide is written as if it were a guide published in 2218, but it is not some flight of futuristic fancy. As an astronomer and planetary scientist, Jim Bell has based his book on scientific data from Solar System exploration missions. At the same time, he is dreaming big, believing that humanity will someday become a multi-planetary species.

"You can reach the Moon using traditional chemical propulsion technology quite similar to what brought the first astronauts to the Moon in three days, but you can cut down significantly on the transit time by using newer technology: nuclear propulsion engines," is one piece of advice Bell gives not only to future travellers, but also to contemporary readers seeking technological solutions for space travel challenges.

There is advice for all kinds of travellers, from hikers who would love to scale the Solar System's tallest volcano to couples who fancy a romantic dinner surrounded by crystals of ice the size of a billion houses.

The text is illustrated with stunning pictures, retro NASA pull-out posters, clear scientific tables and a history of exploration. It provides useful icons to illustrate historical sites, destinations with high radiation levels or long travel times, and it even gives tips on what to wear. On Venus, for example, "if you want to go out onto the surface, you'll have to learn how to operate a hotsuit, which is a sort of cross between an Apollo-style space suit and a highly reflective metallic coat made out of titanium".



Fancy climbing the Solar System's highest volcano, Olympus Mons? This book will show you how

NASA/JPL

This book is perfect for anybody who already feels like a space tourist, but also for anyone who believes that the Solar System is a beautiful place worth exploring. It is definitely not written 200 years too early, because it makes you feel like packing already.

★★★★★

SANDRA KROPA *is a science journalist and writer*

TWO MINUTES WITH Jim Bell

How far away is true interplanetary tourism?
If you believe that SpaceX might offer a trip around the Moon to some wealthy tourists soon, we're already there. We've reached a point when rich folk can start to engage in interplanetary tourism, though in a limited capacity. I'm more interested in when the costs come down into the range of the middle classes, and when the business world starts to develop the infrastructure to support interplanetary tourism (hotels, restaurants, attractions). In my book I claim all of that will be 'routine' by 200 years from now, but when will it start? 50 years from now? 100? 500? I do think it is inevitable.

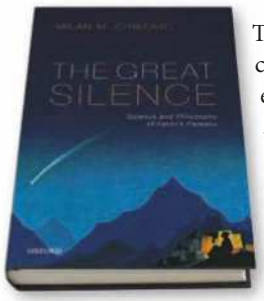
Which other planet or moon would be easiest for us to live on?
Probably Mars, because we know that so many of the raw materials we'd need – water/ice, oxygen, soil – are already there. Plus it's a rather Earth-like place in many respects (length of day, familiarity of geology), and not too far away in case help is needed from the home planet.

Which of the tourist activities in the book would you most like to do?
Oh my gosh, how to choose? I really do want to go to the Moon for the weekend some time (I've told my kids it would be a great 100th birthday present) and I'd love to visit Mars… And stand under a propane waterfall on Titan… And jump off a 10km cliff on Miranda. But perhaps the most important thing is that afterwards I'd definitely want to come home to Earth.

DR JIM BELL *is a professor in Arizona State University's School of Earth and Space Exploration*

The Great Silence: Science and Philosophy of Fermi's Paradox

Milan Ćirković
Oxford University Press
£25 ● HB



To date, we have confirmed the existence of over 3,700 planets in the Milky Way, yet we still have no proof of life beyond Earth. Our Galaxy is not particularly special, so where is everyone? This question forms the basis of Fermi's paradox, an argument put forward by 20th century physicist Enrico Fermi.

Through a challenging but fascinating combination of philosophy and science, *The Great Silence* tackles this question. Except, instead of just pondering endlessly about alien life, Cirkovic critically reviews a variety of resources to determine the best way to progress towards a solution of Fermi's paradox. After focusing on the astrophysical and philosophical background, where we are introduced to the story behind the paradox, we converge on four main branches of solutions. These include the rare-Earth and neocatastrophic hypotheses which, in turn, encapsulate several smaller ideas. The final chapter aids comparison between solutions via a useful A-F grading system.

Full of brilliant diagrams and thought-provoking content, this book is well organised and, for the most part, is divided into manageable sections. However, it's not a casual read and doesn't pretend to be.

From the start the writing is challenging, with new ideas being introduced in quick succession. These ideas are explored fully in later chapters, but can initially be intimidating – especially if, like me, this is your first major foray into philosophy.

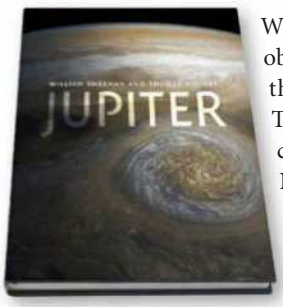
Overall, this is a worthwhile read, but not one for the faint-hearted, and I expect it will take you a few attempts to fully appreciate its compelling content.

★★★☆☆

AMBER HORNSBY is a postgraduate researcher at Cardiff University

Jupiter

William Sheehan, Thomas Hockey
Reaktion
£25 ● HB



What was the first object you ever saw through a telescope? There's a very good chance it was Jupiter. No wonder, then, that the planet has obsessed observers for millennia.

In this superbly researched and illustrated guide to the giant planet, the authors have trawled through centuries of humanity's archives for documentation of Jupiter, looking for engaging ways to explain what astronomers know about the planet, and how they found out. This stretches right back to Babylonian astronomy and its discovery of synodic periods, which serve as a primer on celestial mechanics and how this 'almost star' was formed.

Although this is definitely not a book to buy for children (the text can occasionally be rather dense), the illustrations are exceptional, reproducing one archive gem after another; even Galileo's observation notes from 1610. Perhaps the most enjoyable chapter is on Jupiter's Great Red Spot, which considers how this area of high pressure has changed over time, and why it mysteriously disappeared from observations for a century. Various archive sketches of Jupiter jostle for space with more recent photos captured by the NASA Juno spacecraft.

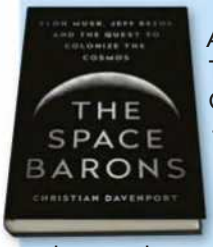
Some might think this 190-page book should have waited until after Juno's mission had ended; details of Jupiter's partially dissolved core, the cyclones at its north and south poles, and that its magnetic field is twice as strong as previously thought would have helped make this book definitive. For these updates you'll need to visit the Juno website after you've finished the book. Nevertheless reading this comprehensive primer on Jupiter – and on planetary astronomy itself – is as enlightening as it is thoroughly enjoyable.

★★★★☆

JAMIE CARTER is a science writer, astrophotographer and author of *A Stargazing Program for Beginners*

The Space Barons

Christian Davenport
Public Affairs
£20 ● HB



A century ago, Thomas Edison and George Westinghouse fought for a huge prize: who would dominate the revolutionary new electricity business? Half a century later, Steve Jobs and Bill Gates competed in the similarly significant new realm of personal computing. Now Amazon's Jeff Bezos and Tesla's Elon Musk are scrapping over space transportation, which may yet prove to be a prize as grand as anything that the railroad and automobile barons could have dreamed of.

Davenport's book title is appropriate. Our future in space really is being determined by business 'barons'. On the plus side, this book is lively and accessible. It also benefits from Davenport's direct access to Musk, Bezos, Richard Branson and other leading players. Among many lively and sometimes revealing anecdotes, we learn that Musk's plan to colonise Mars is less important to him than his desire to reach out into space just for the heck of it, while Bezos wants to save Earth by putting heavy industries into orbit. He dismisses Mars as an impractical place to live.

On the down side, and despite Davenport's privileged access, he never truly penetrates the mystery of what drives these men, or who they really are. At times his narrative reads more like public relations than critical analysis. In particular, Branson's slow progress and uncertain business model for Virgin Galactic is not critiqued. However, this is an engaging and informative read, as long as you sprinkle your enjoyment with a hint of scepticism.

★★★★☆

Spaceflight expert PIERS BIZONY *is the author of* The Space Shuttle

Gear

Elizabeth Pearson rounds up the latest astronomical accessories

1 Orbitrack app

Price £4.99 • **Supplier** Southern Stars
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Laser pointers can be useful in leading new astronomers around the sky, but they can lose brightness in the cold. This dew heater will help keep your laser warm and shining bright.

WHAT I REALLY WANT TO KNOW IS...

How will we recognise dark matter?

Richard Massey is trying to entice the most common substance in the Universe to come out of the shadows

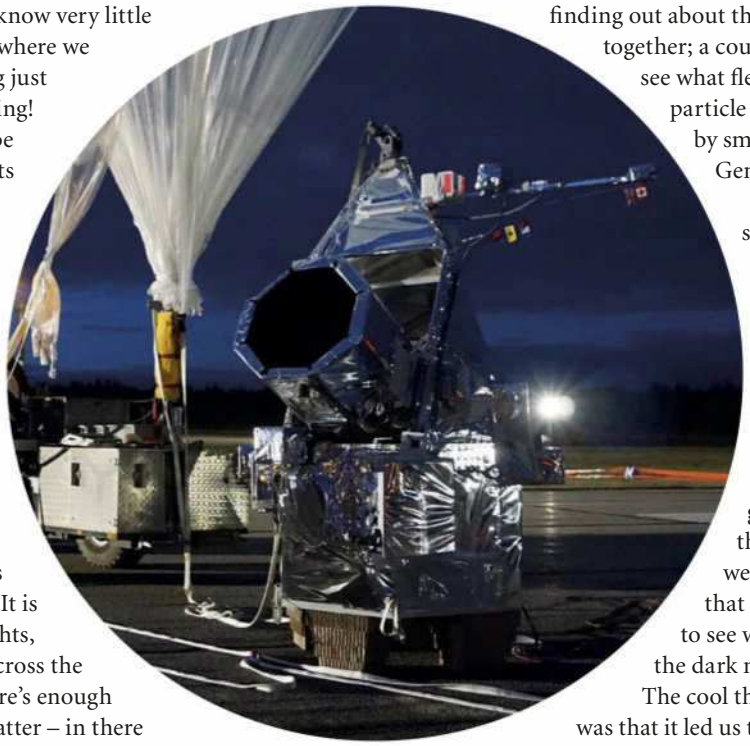
INTERVIEWED BY PAUL SUTHERLAND

Dark matter is the most common substance in the Universe, perhaps accounting for 80 per cent of all matter, yet we know very little about it. Everywhere we look, it's hiding just around the corner. So frustrating!

We know it's there. It must be really heavy, because there's lots of it, and heavy things have gravity, so it pulls things around it. The dark matter in our Milky Way, for example, keeps the Galaxy together.

Imagine visiting a pizzeria where the pizza dough is being spun to flatten it. Fortunately for pizza cooks, the dough is sticky, keeping it as a disc and stopping it from splattering onto the kitchen walls. It turns out the Milky Way is like this. It is spinning really fast and, by rights, the stars should be flung out across the cosmos. Fortunately for us there's enough extra matter – enough dark matter – in there to hold everything together. And yet, embarrassingly, we don't know what it is.

Most of what we know – in fact all we know – about dark matter, are the things it doesn't do. It doesn't shine and it doesn't interact with us in any way we recognise. It doesn't seem to care about the world we live in.



Is it a bird? Is it a plane? No, it's SuperBIT, a dark matter-seeking telescope suspended from a balloon

Show and tell

What we're trying to do is catch it in a rare moment when it may actually care about our world, interact with us in some way and show itself off doing something. And if we see it doing something, that's the first step to figuring out what it is.

Three years ago, there was a glimmer of hope when we thought we'd seen dark matter doing something. The Hubble Space Telescope observed a galaxy in a cluster called Abell 3827, 1.3 billion lightyears away, which initially appeared to show that it was offset from the dark matter surrounding it, as if the two were separating. Sadly, follow-up observations with the Atacama Large Millimeter/Submillimeter Array (ALMA) in Chile showed that this was not the case. So now we're back to trying to catch dark matter in the act of doing something.

Since prehistoric times, humans have been finding out about things by smashing them together; a couple of rocks, for instance to see what flew off. Essentially that's what particle physicists at CERN do today by smashing atoms together under Geneva to see where the bits fly.

We can do pretty much the same thing with dark matter. We can't smash it together ourselves because we can't see it, let alone pick it up. But nature does a lot of these experiments for us. There are big clumps of dark matter out there in the cosmos surrounding all the galaxies, and occasionally they bump into each other. So we've been looking at galaxies that are smashing into each other to see where the stars go and where the dark matter goes.

The cool thing about the false result was that it led us to do lots of theoretical calculations, bringing together particle physicists and astronomers who study things at different ends of the scale. Together, we've worked out loads of tests and predictions for what different types of dark matter might do that are observable, such as changes in the shape of dark matter around galaxies, and in how it's distributed around galaxy clusters.

So what we need to do now is not just to look at one or two galaxy clusters but lots of them. I'm part of an international team that's doing this with an unusual telescope that flies suspended from a balloon. The Balloon-borne Imaging Telescope (SuperBIT) rises above Earth's turbulent atmosphere for a crystal-clear view of the sky. It sees the visible and ultraviolet parts of the spectrum, and can map dark matter in hundreds of clusters.

SuperBIT is the only way we have of doing this experiment. And the technology developed to stabilise a telescope in the stratosphere has added a twist to the new space race. Cheaper than a rocket, it can go high enough to deliver many satellites into orbit, or act as an almost-there launch platform for those that need to go higher.

ABOUT RICHARD MASSEY

Dr Richard Massey scratches his head in frustration as he ponders the nature of dark matter at Durham University's Centre for Extragalactic Astronomy

SUPERBIT/STEVEN LI

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THE SOUTHERN HEMISPHERE IN JUNE

With Glenn Dawes

WHEN TO USE THIS CHART

1 JUNE AT 00:00 UT
15 JUNE AT 23:00 UT
30 JUNE AT 22:00 UT

The chart accurately matches the sky on the dates and times shown. The sky is different at other times as stars crossing it set four minutes earlier each night. We've drawn the chart for latitude –35° south.

JUNE HIGHLIGHTS

Vesta is unique as the only minor planet that can be visible to the naked eye at some oppositions. These happen every 1.4 years, but you need those that occur in May, June or July (near Vesta's perihelion). Vesta commences June at mag. +5.7, 2.6° north of Mu Sagittarii. On June 19, it reaches an impressive mag. +5.3. Passing 0.5° south of the cluster M23 on the 15th, it closes the month 1.2° north of 58 Ophiuchi. Try sketching the field and the bright 'star' that moves from night to night.

STARS AND CONSTELLATIONS

June evening skies can give magnificent views of the southern Milky Way. For light-challenged suburbanites, there are obvious markers to show its location. Low in the west find Sirius, then head eastward through the False Cross, then the Southern Cross, its pointers, Scorpius, Sagittarius and around to Altair. There are two bright nebulae/star cluster regions worth pursuing, around Eta Carinae (halfway between the two crosses) and the galactic centre (close to the Teapot's 'spout' star). Good luck!

THE PLANETS

The evening sky is rich in planets this month. Low in the northwest at the end of twilight is the brightest planet, Venus. At this time, Jupiter is well placed in the northeast with Saturn low in the east. This ringed world, located near the Teapot of Sagittarius, is at opposition, so is at its brightest and visible the whole night. Following Saturn two hours later is brilliant Mars. Finally, Mercury rises out of the Sun's glow, setting around the end of evening twilight by month's end.

DEEP-SKY OBJECTS

June evenings find the constellation of Boötes sitting on the northern horizon. From its brilliant alpha star, Arcturus, move 6.5° east-southeast to discover naked eye Pi Boötis (RA 14h 40.7m, Dec +16° 25'). It's an impressive double star consisting of two white companions of mag. +4.9 and +5.8, separated by a snug 5.4". To see a double with colour, continue 3.7° northeast to Xi Boötis, with yellow (mag. +4.8) and orange (mag. +7.0) stars, 6.2" apart.

Returning to Arcturus, scroll 9.6° north-northwest to the unusual globular NGC 5466, pictured (RA 14h 05.4m, +28° 32'). This mag. +9.0 star cluster is comparatively loose, with no bright core. The hazy, blotchy disc (6' diameter) is accompanied by a scattering of faint stars across its surface.

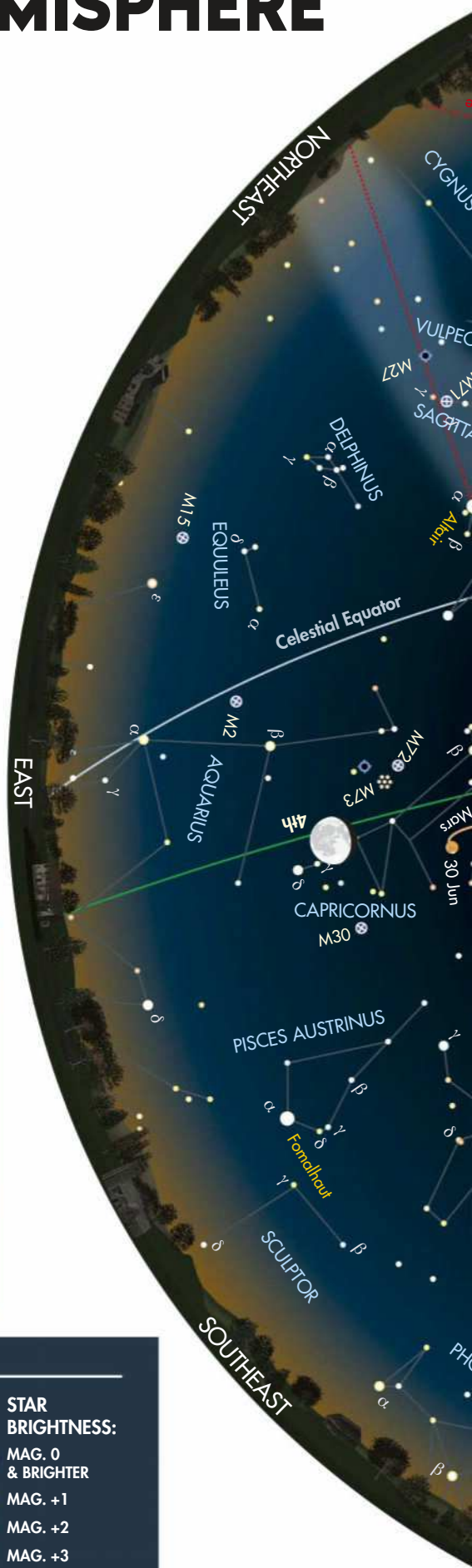
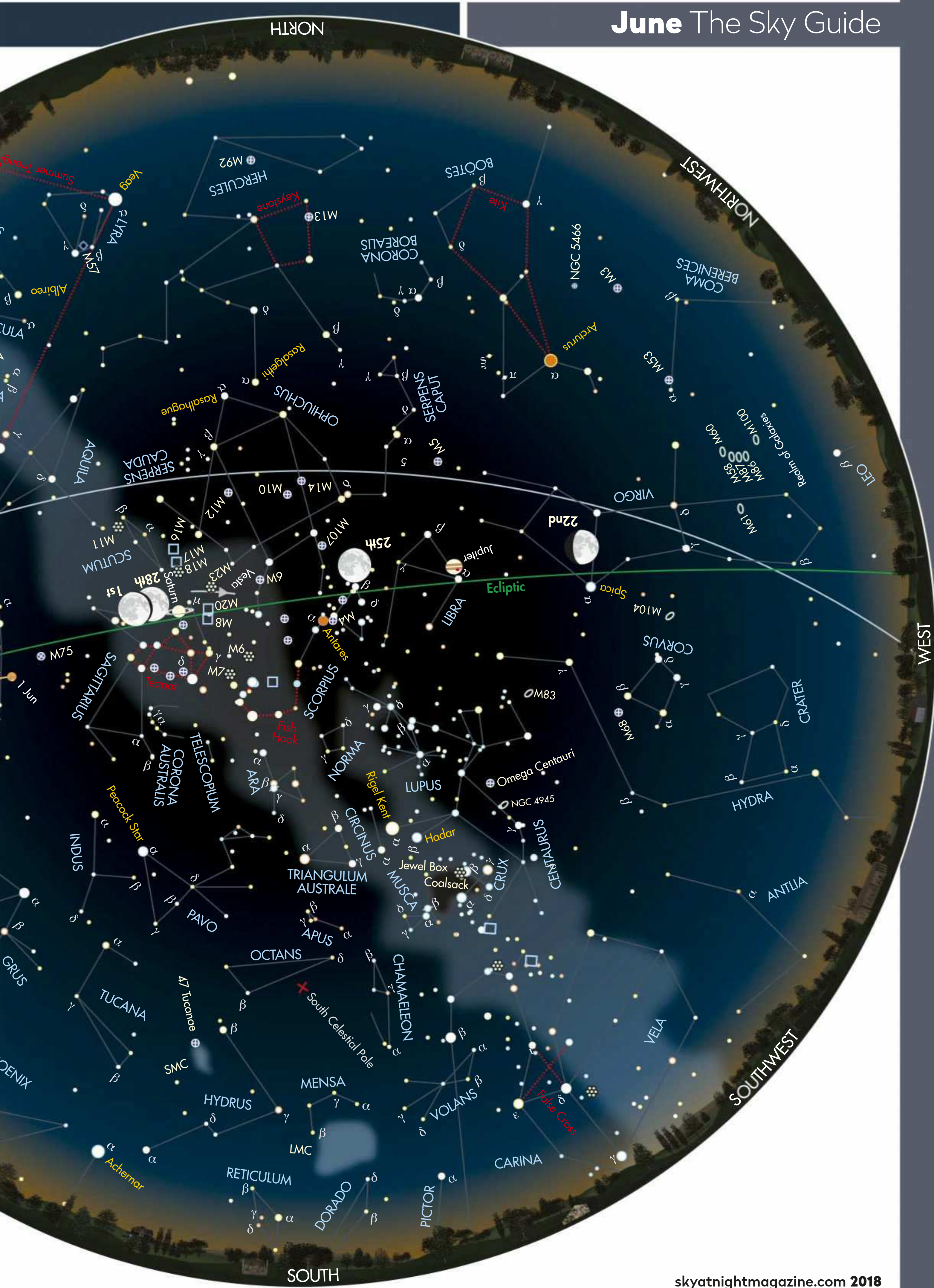


CHART KEY

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE, IMAGE: GÜNTER KERSCHHUBER/CCDGUIDE.COM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M57
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Summer Triangle
BOÖTES
Kite
CORONA BOREALIS
NGC 5466
M3
COMA BERENICES
Arcturus
M53
SERPENS CAPUT
OPHIUCHUS
Rasalgethi
Rasalhague
AQUILA
SERPENS CAUDA
M5
M10
M14
M12
M107
M11
SCUTUM
M16
M17
M18
M23
M9
Vesta
Saturn
28th
1st
25th
22nd
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M61
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M86
M60
M100
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M8
M75
M4
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M6
M7
Teapot
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1 Jun
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M83
M68
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